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THE USE OF WEATHER BUREAU DATA IN ECOLOGICAL STUDIES[1]

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For well over a century ecologists and foresters have included in their reports of investigations of local areas, summaries of climatic data from nearby weather stations. These summaries may reflect the macroclimate of a region, thus serving to locate the area in plains, desert, forest or tundra But they do not account for the various biotic phenomena described, such as occurrence, growth, survival, succession, reproduction and death of plants and animals. Rarely do the authors make any statements concerning relationships between these factors and the biological phenomena observed in the field It may be that there are none that are cause and effect relationships

The meteorological data obtained at Weather Bureau stations form the basis for generalized concepts of phenomena making up a regional climate. These regional climates are clearly recognizable, and in this sense, are comparable to the generalized soil types such as Marbut (15) has recognized in his delineation of the major soil types of the United States But the pedologists have gone further, mapping local variations in soils within the great divisions. Ohio, for example, lies within one of the nine divisions known as the gray-brown podzolic soils province. But in Licking County alone, 56 types and phases are recognized and mapped (32). In the more deeply dissected terrain of Adams County, 68 types and phases are mapped (24).

Studies of local climatic differences, or microclimatic types, comparable to these studies of the pedologists have scarcely been begun by climatologists, although the local microclimates are similarly varied and complex. Moreover, these local atmospheric conditions are the climates in which plants actually live.

Field reports of ecological investigators invariably include analyses of soil factors, most of which have been directly measured in the problem area. But oddly enough, local climatic conditions have been measured only occasionally within the field of survey Climatic data from the very beginning of meteorological measurements, have been obtained from regular meteorological stations, and here from instruments housed in "standard shelters," located one to 50 miles from, and at elevations several feet to a mile above or below, the areas studied.

Thornthwaite and Leighly (27) remark that "the climate of a region as determined by means of these standardized observations is more or less of an abstraction." Geiger (9) has called the climate determined through data obtained by these methods "human climate," *i. e.*, climate based on weather elements in which humans are most interested with regard to transportation, physical comfort, recreation, harvesting of crops, sale of merchandise, and the like. In short, it is the weather around our heads, physically and psychologically, and

[1]Publication No. 477, Department of Botany, The Ohio State University.

does not even remotely resemble the weather experienced by plants and animals at our feet.

But whatever the label applied to the interpretation of these enormous quantities of data accumulated at stations all over the world, they have been exceedingly significant in at least three respects:

1 They have resulted in a knowledge of the pattern of "human climate" over large areas, probably reaching the best expression in North America in Thornthwaite's classification (25); and for the world in Köppen's system (13).

2. They have enabled climatologists to compute the variation of climatic factors in different large areas for years, decades and centuries, and also the same area from year to year

3. They have brought out a recognition of the duration, extent, intensity, and the periodicity, of certain phenomena such as drouth, precipitation and temperature conditions For example, Visher (30) has utilized Weather Bureau precipitation data as a basis for his maps showing distribution of excessive rainfall. This distribution correlates closely with the Southern Coastal Plain forest formation. Kincer (11, 12) has shown the temperature trend to be upward all over the world during the past century, basing his conclusions on the accumulated data at a number of metropolitan stations with long weather records[2] Marvin (16) has recognized definite precipitation trends of 50 to 100 years at Boston. Thornthwaite's evaporation-precipitation index maps (26) show a remarkable similarity to the known periodic fluctuations in the boundaries between original forest and prairie, and prairie and grassland formations

The files of the Weather Bureau also constitute a vast repository of data likely to be of much value when finally analysed and interpreted. In addition to the actual temperature and precipitation data, many cooperative observers have listed quantities of phenological data, such as the times of bird migrations, the breaking of buds, the flowering of plants, the appearance of certain mushrooms and the maturing of various crops The original records may be a rich source of such data, which, as Wing (33) remarks, "may be better for some wildlife comparisons than the temperature records themselves." The observations of Thomas Mikesell at Wauseon, Ohio, for a period of 40 years are outstanding examples. These are probably the most extensive and complete phenological records in North America, and they have been compiled and published by Smith (22)

In general, however, the Weather Bureau has been most active as a public service through its weather predictions In fact, its primary function has been the forecasting of weather. The accumulation, analysis and interpretation of climatic data have been secondary because of limitations of available personnel.

USE OF WEATHER BUREAU DATA IN ECOLOGICAL REPORTS

It is not the regional factors, however, that control the behavior of plants and animals that live, grow, reproduce and die in the multitude of different habitats in large biotic areas like deciduous forest, prairie, or tundra.[3] Yet, even the most recent ecological literature is replete with uninterpreted Weather Bureau data. The following are only a few random examples. Gates (8), in his paper on the bogs of northern Lower Michigan, states that "the climatic conditions most closely resemble those of the Weather Bureau station at Cheboygan, Michigan," one to 100 miles north of the various bogs and between two of the largest lakes in North America. This remarkable statement, completely contrary to the findings of Cox (6), is followed by some data from this distant station. Pearson (19)

[2]Studies now in progress in the Botanical Laboratories at The Ohio State University indicate that this trend is not as pronounced in rural areas as it is in metropolitan centers, the source of most of Kincer's data.

[3]For another point of view, see Cain's quotation of Clements (2), pp. 11 and 21.

in his paper on the effect of herbaceous vegetation on the regeneration of *Pinus ponderosa*, cites precipitation data from a station six miles away from the experimental plot. Purer (20), who studied the ecology of the salt marshes along 40 miles of the California coastline, refers to temperature, sunshine and precipitation data recorded at San Diego, 35 miles from the farthest station. Stoeckler and Limstrom (23) published a paper on factors influencing reforestation in northern Wisconsin. The area in which the studies were conducted is 10 miles southwest of the station from which the climatic data were obtained. Brown's meticulous 10-year study of Roan Mountain (1) included data recorded at two stations 15 and 18 miles away, and at elevations 2,535 and 4,710 feet, respectively, below the problem area. Oddly enough, length of day, one of the most significant of ecological factors, is rarely mentioned.

MACRO- VERSUS MICRO-METEOROLOGY

The climatological and ecological literature, however, is not without reports showing that conditions, as measured by Weather Bureau standards, are sometimes astonishingly dissimilar from nearby, or even adjacent, plant and animal habitats. Wolfe, Wareham and Scofield (34) report frost free periods of seven different lengths in different habitats of a mile-long valley in central Ohio, ranging from 124 to 256 days. For the same year (1941), a Weather Bureau station nine miles away recorded a frost free period of 144 days They also show that the annual minimum temperatures varied in the habitats in the valley from −25° F. to +32.5° F., compared to the official minimum of −18° F. Annual maximum temperatures varied from 76° F. to 120° F., and the dates of the annual maximum temperatures varied from April to August at the different stations.

The same authors report that the date of the last spring frost in 1941 in the valley varied from April 3 to May 25 These dates are almost identical to the official figures for the whole state of Ohio for 1941. At the 88 Ohio stations the last spring frost came between April 2 and May 25 (4). Thus the frost dates of various stations in a small valley less than a mile in length showed as much variation in 1941 as did the whole network of Weather Bureau stations in the state Data for the first fall frost are even more striking. In the valley the first frost-dates in autumn were recorded from September 26 to December 13. The range for Ohio's 88 stations was October 11 to November 10 (4).

Cox (5), in an intensive four-year study of thermal belts in North Carolina, found, among other things, that the length of the growing season varied from 100 to 232 days at 60 stations. The same author (6), in his pioneer microclimatic study of cranberry bogs in Wisconsin, published a vast amount of soil and air temperature data showing that "great extremes of temperature occur in any bog and there is a wide range of minimum temperature in the same bog," further remarking that when the Weather Bureau station at Lacrosse (20 miles from nearest bog) reports prospective temperatures below 50° F., frost can be expected in the marshes if the night is clear. His report supporting this statement is too detailed for summary here. Malde (14), whose work is in agreement with that of Cox (6), increased the average length of the growing period in Wisconsin bogs from 58 to 118 days by application of sand. The averages are based on an 11-year study. Sinclair (21), working on maximum air temperatures in the desert, found great variation between the levels at 4, 12, 32, 65, 114 and 175 cms. above the soil surface through summer days. Maximum temperature of 122° F. at 4 cms. occurred at 1:00 p. m. At the same hour, the temperature at 175 cm. was 15° lower.

These are only a few examples, but there are many others, some of which are discussed by Geiger (9) in his systematic treatment of "the climate of the layer of air near the ground."

SPATIAL VARIATION IN PRECIPITATION

Spatial variation in rainfall within small areas has been shown by Turnage and Mallore (28), Humphrey (10) and Musson (17) to be very great, sometimes the highest readings differing as much as 30 per cent from the lowest. The numerous maps and tables showing variation in amount of precipitation published by the Muskingum Conservancy Project reveal striking differences in different stations of the Muskingum watershed. The Weather Bureau records themselves, sometimes show great differences in amount of precipitation at stations near each other. The correlation of these figures with biotic phenomena is difficult in light of the data in Table I, from two stations near each other in Muskingum County, Ohio (4).

TABLE I

DIFFERENCES IN AMOUNTS OF PRECIPITATION PER DAY AT PHILO (1) AND PHILO (2)[a]; MUSKINGUM COUNTY, OHIO, IN 1943

Precipitation Difference of:	Number of Days per Month With Varying Amounts of Precipitation												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug	Sep.	Oct.	Nov.	Dec.	Total
Less than .10 ins	16	15	6	14	14	4	7	5	8	8	10	11	118
Between .11-.25 ins	5	1	5	3	5	3	7	0	1	0	1	0	31
Between .26-.50 ins.	1	1	1	2	4	2	2	1	0	1	1	0	16
Between .51-1.00 ins.	0	0	3	0	0	1	0	0	0	1	0	0	5
Over 1.00 in.	0	0	0	0	0	1[b]	0	2[c]	0	0	0	0	3
Total days ppt.	22	17	15	19	23	11	16	8	9	10	12	11	173

[a] Station 2½ miles S.W. of Philo, where (1) is located.
[b] 1.36 ins. at Philo (1); .15 ins. at Philo (2) on June 16.
[c] 1.85 ins. at Philo (1); .40 ins. at Philo (2) on August 4.
1.02 ins. at Philo (2), none at Philo (1) on August 5

While 68 per cent of the total days with at least a trace of precipitation have essentially the same amounts at the two stations, the differences appear to be ecologically significant, especially when using the data in conjunction with seasonal or short-time investigations. Moreover, the major differences occur in the midst of the so-called growing season. These differences may be averaged and the total annual precipitation at two stations located so close together become nearly identical. But in 1943 the total at Philo (1) was 29.25; at Philo (2) 34.24, with monthly differences of 1.10 and 1.04 inches in June and August respectively.

TABLE II

DIFFERENCES IN PRECIPITATION AT TWO FIRST ORDER WEATHER BUREAU STATIONS AT CINCINNATI, OHIO[a] FOR THE 1943 GROWING SEASON

Precipitation Differences of	Apr.	May	June	July	Aug.	Sept.	Total
Less than .10 ins.	17	21	11	9	7	10	75
Between .11-.25 ins	3	2	3	1	1	1	11
Between .26-.50 ins.	0	2	0	5	4	2	13
Between .51-1.00 ins.	0	0	2	1	0	0	3
Over 1.00 ins.	0	0	1[b]	0	0	.0	1
Total days with ppt	20	25	17	16	12	13	103

[a] Stations are located at the Abbe Observatory and the Federal Building, about 3.4 miles apart.
[b] Abbe .55 in.; Fed. Bldg. 1.59 ins. on June 10.

While readings of instruments at the cooperative stations may not always be made at exactly the same hour each day, thus inserting error into the daily comparisons, similar results are obtained in comparing two first order stations at Cincinnati. (Table II).

Moreover, these data usually are concerned only with amount. It has long been recognized that time of precipitation, nocturnal or diurnal; the season, type, amount of interception, run-off, and evaporation are also important ecological factors. But total and average precipitation data are all that are usually published by ecologists, often from stations 20–50 miles from the problem area. It seems useless, therefore, to cite precipitation data not obtained in the problem area. The precipitation data represented by Fig. 1b, for example, implies a rather uniform distribution through the seasons at Lancaster, Ohio. Figs. 1a, c plainly show that this is not true, and may frequently be misleading.

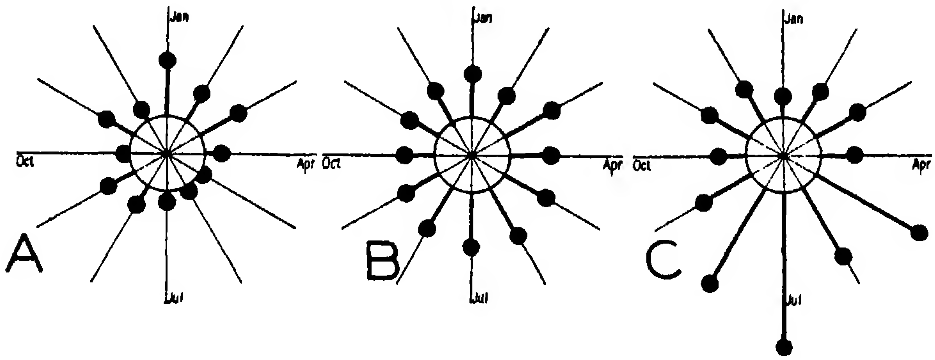

FIG. 1. Precipitation rosettes for Lancaster, Ohio. A, monthly precipitation in 1930, showing year-round drouth conditions; B, mean monthly precipitation giving the impression of rather uniform seasonal distribution; C, monthly precipitation in 1920, showing winter drouth and abundant rainfall during crop growing seasons.

WEATHER BUREAU METHODOLOGY AND PROCEDURES

Weather Bureau methodology and procedures fail to furnish useable ecological data, *i. e.*, data reflecting actual habitat conditions of plants and animals, for several reasons

1. *Location, Housing and Reading of Instruments:* Not only are the instruments placed five feet above the substrate, but that substrate may be anything from the tar and gravel roof-top of a 90-foot building in a metropolis, to the bluegrass lawn of an airport, or the unsodded terrain of a farmer's barnyard. Moreover, the instruments, located as they are, in standard coops, are sheltered from almost every condition to which plants and animals are subjected, *i. e.*, wind, rain, snow, insolation, nocturnal radiation to the sky, other plants and animals, and the character of the substrate or soil. Thornthwaite and Leighly (27) have observed that "the range in mean monthly minimum temperature [may be] as great within five feet of the ground vertically as in a belt 300 miles from north to south at the standard level." In Table III are some minimum temperature data obtained in the Botanical Gardens at The Ohio State University. Data included in the table were obtained in February and March, 1944. Temperatures at the five-foot level were obtained by using a standard Weather Bureau thermometer, housed in a shelter similar to that of the Weather Bureau type. Utilizing a technique employed by Wolfe, Wareham and Scofield (34), temperatures were also obtained with three thermometers at the eight-inch level

TABLE III

COMPARISON OF MINIMUM TEMPERATURES RECORDED BY VARIOUSLY EXPOSED THERMOMETERS IN THE OHIO STATE UNIVERSITY BOTANICAL GARDEN WITH THOSE OF NEARBY WEATHER BUREAU STATIONS

1944	Exposed, face up	In therm. holder	Beneath board	Standard shelter	Col's, O., W. Bureau	O. S. U. W. Bureau
Feb. 20	5.0	8.0	14.0	14.0	25	23
Feb. 21	12.0	13.0	19.0	21.5	26	27
Feb. 22	27.5	31.0	29.0	34.0	38	38
Feb. 23	34.5	35.5	35.5	36.5	37	38
Feb. 24	20.5	23.0	29.0	27.0	37	35
Feb. 25	16.0	18.0	22.0	23.5	35	31
Feb. 26	42.0	40.5	43.0	43.5	48	44
Feb. 27	32.0	34.5	37.5	39.5	37	41
Feb. 28	32.0	32.0	33.5	33.5	31	34
Mar. 1	21.0	21.0	23.5	22.5	24	25
Mar. 2	3.0	6.0	12.5	12.5	22	20
Mar. 3	.	19.0	23.5	22.5	32	31
Mar. 5	17.0	15.5	18.0	16.5	18	19

TABLE IV

DISTRIBUTION, ACCORDING TO AMOUNT, OF 415 CONSECUTIVE RAINFALLS OF .05 TO .37 INCHES, AT LANCASTER, OHIO

Amount	Number	Amount	Number	Amount	Number
.05	34	.16	11	.27	13
.06	8	.17	4	.28	4
.07	3	.18	13	.29	4
.08	15	.19	12	.30	27
.09	8	.20	21	.31	3
.10	27	.21	14	.32	15
.11	5	.22	9	.33	7
.12	17	.23	7	.34	8
.13	9	.24	8	.35	24
.14	4	.25	28	.36	11
.15	30	.26	12	.37	5

TABLE V

DISTRIBUTION OF DAILY MINIMUM TEMPERATURES BETWEEN 28° F. AND 36° F. AT LANCASTER, OHIO, OVER A 42-YEAR PERIOD (OCTOBER–APRIL)

MONTH	TEMPERATURE °F.									
	28°	29°	30°	31°	32°	33°	34°	35°	36°	Total
October	17	22	29	36	33	40	43	52	55	327
November	54	60	66	44	61	63	50	55	49	502
December	59	47	48	46	65	31	24	45	18	383
January	55	38	60	24	44	29	46	30	26	352
February	42	30	51	35	59	31	31	35	18	332
March	39	65	74	54	72	40	36	45	28	453
April	27	34	51	39	46	42	49	56	37	381
Total	293	296	379	278	380	276	279	318	231	2730
Percent	10.7	10.8	13.8	10.2	13.9	10.1	10.2	11.6	8.4	99.7

above a blue-grass sod. One thermometer was placed face-up, on a platform constructed of redwood; another was attached below the platform; another was placed in a holder described by the above writers, at the edge of the platform (Fig. 2). Temperatures recorded at the Columbus Weather Bureau and the cooperative station at the Ohio State University are included in the table. From these data it is obvious that it is not to be assumed that minimum garden temperatures are similar to temperatures recorded by the Weather Bureau or its cooperative station. On cloudy or rainy nights, the minimum temperatures may vary only a few degrees, but when there is much radiation to the open sky, differences may amount to as much as 12° F., even in the seclusion of standard shelters. Instruments not so sheltered show even greater differences and further experiments may show these figures to be most applicable to indicate the temperature conditions to which the plants are subjected.

FIG. 2. Photograph of the platform to which variously exposed thermometers were attached to obtain air temperatures at the eight-inch level over a bluegrass sod.
Photo by A. Hyder.

The effectiveness of the Weather Bureau set-up in the United States is in great part made possible through the cooperation of 5,000 or more voluntary observers. There are certain features of this system, however, which frequently are sources of slight error. The change of location of the cooperative stations, sometimes entailing significant changes in elevations; lack of uniformity in hours of observation, and breaks in the continuity of the records when the observers retire, are ill, or go on vacation, make certain comparisons of data difficult. Moreover, the data presented in Tables IV and V indicate that the readings may not be exact. All of these, however, may have but little effect on data desirable to the Weather Bureau, nor are they a source of serious error in the compilation of macro-climatic data.

2. *Modification of Observers' Data.* A study of the original records (18) of Ohio cooperative observers on file at the Columbus Weather Bureau, indicates

that some of the observations recorded by the cooperators are subject to modification by their supervisors at the main office. This often leads to false analysis of factors ecologically significant, especially with regard to temperature phenomena.

For example, on the morning of June 23, 1918, at Lancaster, Ohio, the observer recorded a minimum temperature of 40° F., and accompanied the record with a written statement, "Killing frost," adding: "Considerable damage to corn and tender vegetables." The published record (3), however, states that the final spring frost for Lancaster in 1918 was on April 14, 70 days earlier. Moreover, the last "freeze"[4] was recorded on April 25, eleven days after the last official frost. Perhaps no frost occurred the morning of April 25, but it seems unlikely, although entirely possible if surface temperatures were above 32° F. Further study of the Ohio record reveals that this modification is not an uncommon occurrence. (Table VI.)

TABLE VI

LENGTHS OF FROST-FREE PERIODS AT LANCASTER, OHIO, FOR SELECTED YEARS, BASED ON THREE DIFFERENT CRITERIA

Year	Weather Bureau			Observer			32° F. Temp.		
	Last Spring	First Fall	Length in Days	Last Spring	First Fall	Length in Days	Last Sub 32° Spring	First Sub 32° Fall	Length in Days
'05	4/24	10/23	182	None	10/23	... ...	4/24	10/13	172
'18	4/14	11/2	202	6/23	9/22	91	4/25	11/2	191
'21	4/18	10/13	178	5/1	None	..	4/8	10/13	188
'23	4/26	10/5	162	None	9/14	......	5/9	9/16	130
'26	4/27	11/1	188	None	10/7	......	5/11	10/7	149
'27	4/24	11/6	206	None	9/21	.....	5/1	9/21	143
'29	5/8	10/18	163	None	10/18	....	5/8	9/19	134
'32	5/3	10/22	172	5/3	10/22	172	5/3	10/14	164
'35	5/1	10/5	157	None	9/30	....	5/1	9/30	152
'36	4/25	10/28	186	None	10/28	....	4/25	10/3	161
'37	5/11	10/14	156	None	10/8	....	4/12	9/18	159
'38	5/13	10/28	168	5/12	10/28	169	5/13	10/7	147
'39	5/4	10/15	164	5/1	10/15	167	5/4	10/13	162
'40	5/5	10/17	165	5/5	10/17	165	5/5	10/9	157
'41	5/25	10/29	157	None	10/29	......	5/25	10/11	139

Calculation of the length of the frost free period is subject to additional errors because observers may not report frosts when they do occur. Then the officials use the last 32° F. temperature in spring and the first in the fall, but as indicated in Table VI, may also do so whether or not the observer reports frost. The use of two criteria in determining the frost free period leads to some inaccuracy, although as far as macroclimate is concerned, the error may be insignificant. However, whether the frost free period in 1918 at Lancaster was 91, 191 or 202 days, is difficult to determine.

3. *Methods of Compiling and Incompleteness of Data:* The Weather Bureau records have definite limitations as a measure of ecological factors because of the incompleteness of certain observations. When light is measured, it is usually in terms of total hours of sunshine; relative humidity data are reported only three times daily; persistence of snow cover data are fragmentary or lacking; wind

[4]The term "freeze" is used by the Weather Bureau to refer to conditions when the temperature inside the standard shelter is 32° F. or lower. Frost may be recorded when the temperature inside the shelter is as high as 51 F. (Bowling Green, May 12, 1898. (18)). At Lancaster, O., however, the 50-year average date of the first fall frost is Oct. 15 and the average date of the first fall freeze falls six days earlier.

velocities are either not measured or if so, the data are not applicable to ecological problems. It is not uncommon in Hocking County, Ohio, for winds of gale velocities to roar through the pine forests on the uplands, yet on the forest floor of the lower valley, the leaves of plants in the herbaceous layer do not move perceptibly. No satisfactory method of measuring evaporation has ever been developed; precipitation in the form of dew and frost is not measured. Soil temperature and depth of freezing data are lacking and fragmentary.

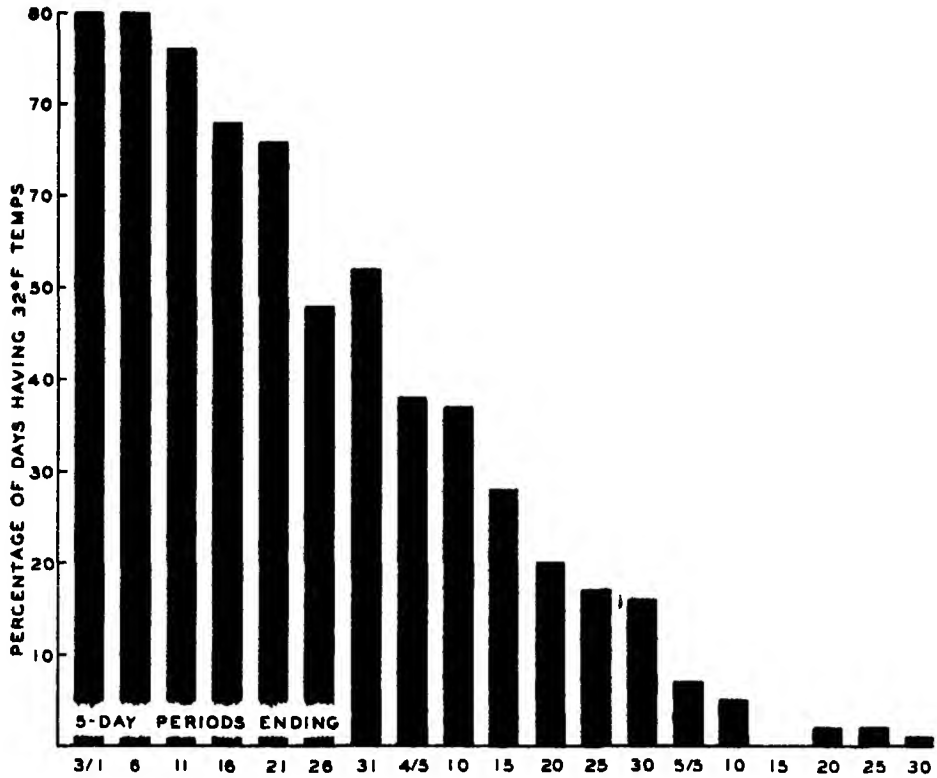

FIG. 3. Frost probabilities for successive five-day periods in spring at Lancaster, Ohio, based on 25-year records from 1910

Largely because the Weather Bureau data are compiled on a monthly rather than seasonal basis, ecologists publish these data as though each calendar month itself is an ecological factor. Table VII shows how misleading temperature data can be when presented on a monthly basis.

TABLE VII

AVERAGE AND EXTREME TEMPERATURES (°F.) FOR FIVE-DAY PERIODS AT LANCASTER, OHIO, 1910 1935

APRIL	1-5	6-10	11-15	16-20	21-25	26-30	1-30
25 year Average.......	48 6	49 4	50.7	52 9	52.7	53 9	51 3
25 year avg. maximum	60 4	60 9	62 7	64 5	64 6	65 6	63 1
25 year avg. minimum	36.9	37.9	39 0	40.9	41 1	41 9	39 6
All time maximum*	83 0	86 0	89.0	88.0	89 0	92 0	92 0
All time minimum*	9 0	19.0	22 0	19 0	21 0	23 0	9 0

* 1895–1943.

This is further emphasized when considering probability of frost damage. Figure 3 is based on the frequency of spring frosts during five-day periods over a 25-year span, at Lancaster, Ohio. The percentages indicate the probability of frost during these short periods, from February 26 to May 30.

Although of lesser importance to the ecologist than to the agriculturist, the sub-division of the various states into climatic divisions appears in many cases not to have been done on either a climatic, biotic, or physiographic basis or a combination of the three. Ohio, for example, is divided into "northern," "middle"

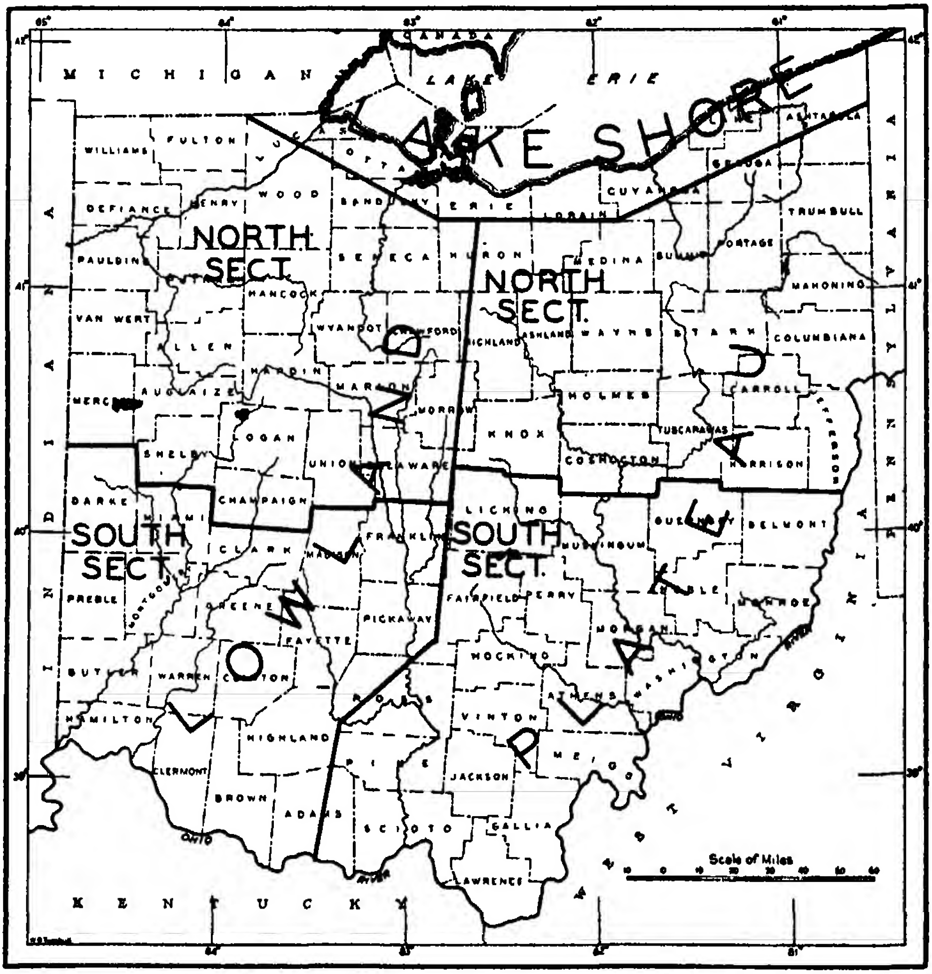

FIG. 4. Suggested subdivision of Ohio for climatic comparisons. This takes into account the effects of the plateau and lake on climate, which physiographic features overshadow the effects of latitude. In western Ohio the influence of physiography is less marked.

and "southern" divisions, apparently on what may be considered a doubtful assumption, stated by Fisher (7) that "probably the greatest variations in the climate [of Ohio] are those incident to latitude." A more desirable subdivision, which would lead to better comparisons, is suggested in Fig. 4.

This analysis of Weather Bureau data, as used by ecologists, is in no way a reflection on the work of the Bureau and its thousands of cooperative observers.

They have contributed abundantly to one phase of human knowledge. Rather, the data seem to emphasize the need for a different approach to climatic and weather problems as related to agriculture, forestry, ecology and conservation. "Knowledge of human climate," as Geiger (9) remarks, "has now reached a stage of tentative finality." With the broad generalizations developed, they stand as a basis from which to work out the variations and trends in the many habitats located within large areas. This is the province of microclimatology.

SOME PROBLEMS OF MICROCLIMATOLOGY

Microclimatology, or ecological meteorology, however, is confronted with a number of major problems which will have to be solved before satisfactory data can be obtained and adequate correlations made with carefully observed biotic phenomena. Four of the principal problems are mentioned below

1. *Instrumentation.*—The development of new instruments and the modification of old ones is necessary to meet the difficulties connected with the measurement of factors in the habitats. Many present instruments were constructed for laboratory use, or for use in protected shelters, or have been placed where they could be frequently and easily adjusted.

2. *Experimentation in Methods* Much needs to be done in determining what methods most accurately measure ecological factors in the field In a leading ecology textbook there is the remark: "With the aid of a thermometer, the measurement of temperature is an easy task" (31). The reading of a thermometer is easy, but "of what is that reading the temperature?" is another question indeed

3. *Accumulation of Phenological Data*—Published records of observations of plants and animals in the habitats where the factors are being measured are notable by their absence. Even though it be assumed that Weather Bureau data reflect actual habitat conditions for a given region, observations relative to date of planting, beginning of growth, time of germination, period of greatest vegetative growth, time of flowering, time of maturation of fruit, quality and quantity of the crop are almost totally lacking or exceedingly fragmentary or unreliable.

4. *Facilities for a Long-Time Research Program.*—Thornthwaite and Leighly (27) have outlined a research program which would attempt to meet these problems as well as many others They suggest that such a program be connected with a large university, so that space, diverse facilities of the various related science departments, and manpower could be available. This appears to be an excellent method of approaching the present and future problems of ecological meteorology.

SUMMARY

1. Weather Bureau meteorological data have been the basis for the development of climatic concepts, and evidence of climatic trends over large biotic areas such as desert, prairie and forest.

2 Weather Bureau records have been re-published extensively by ecologists in conjunction with ecological studies, but correlation of biotic phenomena with the climatic data has not been explained or demonstrated.

3. There is wide variation between macroclimates as determined from Weather Bureau data and the actual (microclimates) to which biotic communities are subjected and by which they are limited.

4. Weather Bureau data are not applicable when explaining such biotic phenomena as growth, reproduction, succession and death of plants and animals in various habitats of a region.

5. There appears to be an urgent need for direct measurements of microclimatic phenomena in the analysis of many problems of agriculture, forestry, ecology and conservation.

6. Further advances in a knowledge of microclimates depend upon the develop-

ment of new instruments and methods, the accumulation of precise phenological data in the habitats or fields where the factors are being measured, and the establishment of facilities for a long-time research program.

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STUDIES IN HUMAN INHERITANCE XXVII

The Inheritance of the Shape of the Sella Turcica[1]

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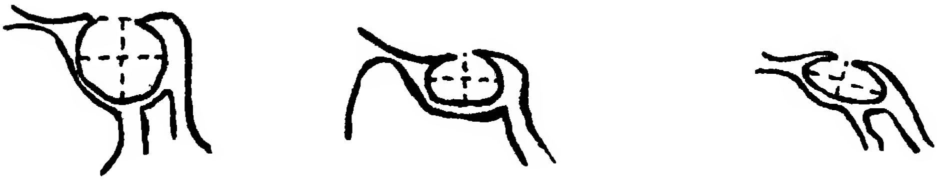
The shape of the sella turcica as seen in X-ray pictures varies from circular through oval to flat or saucer-like. Almost nothing is known as to the possible genetic basis for such differences in shape. Dillon and Gourevitch (1934, 1936) observed the variation in sella form in 26 pairs of twins, 14 fraternal and 12 identical, and concluded that these variations were chiefly influenced by genetic factors. Maguid (cited by Dillon and Gourevitch) compared four pairs of identical twins with four pairs of fraternal twins, and found striking similarities in sella shape in the identicals and marked differences between the members of the pairs in the fraternal group.



I II III

FIG. 1. Diagrammatic representation of the three shapes of sella turcicas. I, round; II, oval; III, flat.

In the course of a genetic investigation of the variation of pneumatization of mastoids, configuration of sinuses, and form of sellas, we have taken standard X-ray pictures of parents and children. In a preceding paper (Snyder and Blank, 1944) we presented evidence that bridged sella is inherited on the basis of a dominant gene substitution. It is the purpose of this paper to present the results of our analysis of sella shape based on X-ray pictures of 100 individuals belonging to 24 families.

Knowledge of the possible genetic factors underlying sella shape may be of practical as well as theoretical importance, since the size and shape of the pituitary gland is obviously proportional to the form of the sella turcica which houses it. The secretory function of the gland may or may not be related to its size and shape, but the genetic study of such conditions as Froehlich's disease, Simmond's disease, adiposity and short stature requires a better knowledge of variation in the sella turcica than we now possess.

The X-ray pictures were taken in the standard position for lateral radiography of the sella turcica. The work was done at St. Francis Hospital, Columbus, Ohio. The distance was in all cases the same and was sufficiently great to avoid distortion.

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[1]The authors gratefully acknowledge the receipt of a grant from the Committee on Human Heredity of the National Research Council, which made possible these studies.

[2]Chairman, Department of Zoology and Entomology, and Professor of Medical Genetics, Department of Medicine, The Ohio State University.

[3]Medical Director, Bureau of Human Heredity, London, England; Guest Investigator, The Ohio State University.

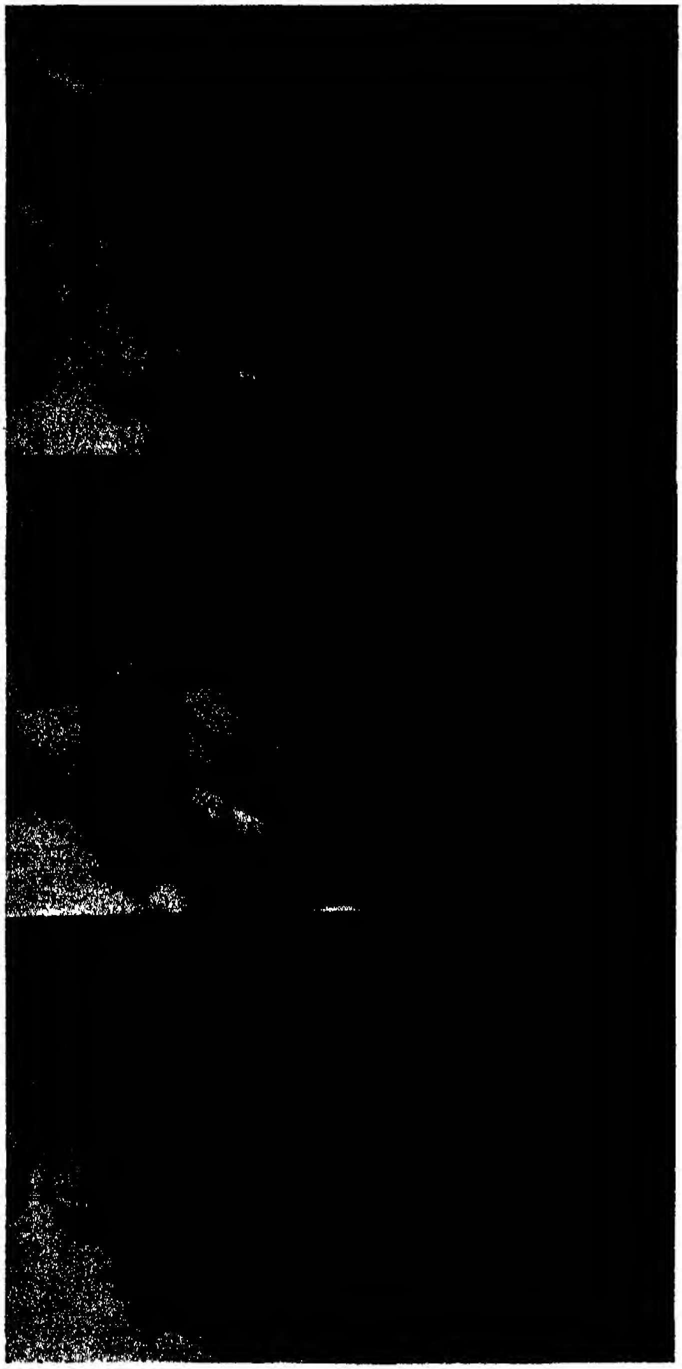

FIG. 2. X-ray photographs of the three types of sella turcicas. Upper, round; middle, oval; lower, flat.

The sellas were measured in two dimensions: saggittal, the maximal anterior-posterior distance, and vertical, the distance from the middle of the base to a line connecting the tips of the anterior and posterior clinoid processes (Fig. 1). It was found that the ratios between width and height fell into three rather sharply defined groups with very little grading from one to the other (Fig. 2). The three groups were as follows:

I circular; width to height being about 1 : 1.
II oval; width to height being about 1.5 : 1.
III flat; width to height being about 2 · 1.

The proportions of the three groups in our one hundred cases were as follows: type I, 41 per cent, type II, 50 per cent, and type III, 9 per cent. These proportions differ somewhat from those reported by Koehler (1928) on 500 X-ray pictures of normal European individuals, where the figures were type I, 24.4 per cent, type II, 58.4 per cent, and type III, 17.2 per cent. It would not be surprising to find racial and group differences in sella shape as have been found in skulls.

The types of mating in our material and the offspring from these types are as follows:

Mating Type	No. of Families	Offspring		
		I	II	III
I x I	3	6		
I x II	11	12	11	1
I x III	1	4		
II x II	5		10	
II x III	4		5	3
III x III				

It is clear that there is a correlation between types of parents and types of offspring However, with the small number of individuals a trustworthy estimate of the association can not be obtained. The data are highly suggestive, and indicate the action of Mendelian factors in the production of sella shape The collection of further data seems justified, and it is hoped that these studies, interrupted by the exigencies of the war, may be continued when the opportunity again presents itself.

Unusually small sellas were encountered in two families. In one family the mother and both of her sons showed the trait; in the other, the father and one of two sons had the small sellas.

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THE SIMILARITY EXISTING BETWEEN SOME ALGAE AND SOME POLLENS WITH A FURTHER NOTE CONCERNING PHYTOMORULA REGULARIS KOFOID[1]

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Herbert F. Copeland (1937) pointed out the similarities existing between certain Mimosoideae pollen and Kofoids algal genus Phytomorula. This paper, in Madroño, appears not to have had the wide circulation among algologists which it deserved.

To anyone who has seen pollen from such species of Acacia as *A. longifolia*, *A. baileyana*, or *A. verticilata*, there can be no doubt as to the accuracy of Copeland's conclusions. A discrepancy which he mentions, however, does exist between the two published figures of *Phytomorula*. That by Kofoid (1914) shows a small dome-like protuberance on each cell, while Smith's figure (1933) shows a larger, broad protuberance. Copeland was not able to explain this discrepancy, although he suspected that the shape of the protuberance was dependent upon the degree of exposure to which the pollen cluster had been subjected. The present work appears to verify these suspicions.

The writer, in organizing a reference collection of pollen in connection with a study of fossil and subfossil algae of Ohio Bogs, noted the similarities as well as the discrepancies existing between Acacia pollens and the figures of Phytomorula. In an attempt to find a suitable method of preparing pollens for study, the reasons for these differences became evident. A pollen cluster of Acacia when taken directly from the flower and shown in Fig. 1c, shows the broad protuberance on the outer face of each cell. When such a cluster is treated with various mounting media, a distinct shrinkage is evident, resulting in small dome-like protuberances as figured by Kofoid, Fig. 1a. If the shrinkage is controlled by varying the concentration of the media, clusters will be found in which some of the cells show the small dome-like protuberance, while others exhibit no sign of shrinkage, Fig. 1b. Figure 1d is a copy of Smith's figure of Phytomorula.

Such differences in the contour of cells of Acacia pollen clusters therefore appear to be due to varying periods of exposure before collection. The discovery of the true nature of Phytomorula by Copeland is an excellent example of the implications which may be evident to the algologist and non-algologist alike.

With the recent advance in the study of fossil pollen and fossil algae in peat deposits, the need for a reciprocal knowledge of their respective fields by the pollen analyst and algologist is evident. As both pollen and algae occur interspersed in the same deposits, it is sometimes very difficult to identify them with any degree of certainty unless they or their near relatives have been previously encountered in living condition.

The foregoing example is merely a case where the algologist was led into committing an error because of a lack of information concerning pollen structure. If we look at the other side of the fence, we find possibilities of pollen workers committing the same kind of errors. If there is so great a resemblance in one direction, then there may be a possibility of the situation being reversed. In substantiation of this, there is a genus of the unicellular algae, *Trochiscia*, the species of which are identified entirely on wall characters. Species having reticulate,

[1]Paper from the Department of Botany, The Ohio State University. No. 481.

spiny, or otherwise sculptured walls might easily be mistaken for pollens. Also that certain pollens might be assigned to this genus by the inexperienced algologist. Another error, and one which I feel may have been committed in some instances, is the identification of the cysts of certain species of *Trachelomonas* as grass pollens. This genus, a relative of Euglena, is characterized by having the individual surrounded by a silicious cyst with one pore. A study of the cyst, however, will readily distinguish it from pollens.

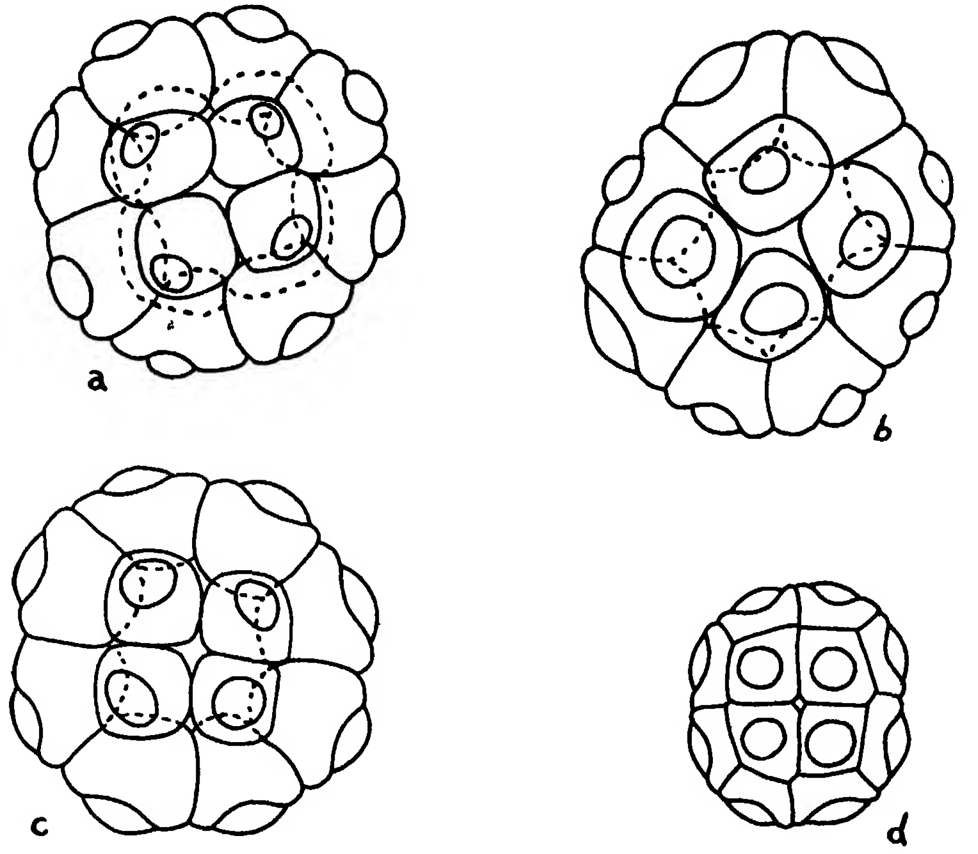

FIG. 1. a—Kofoid's figure of *Phytomorula regularis;* b—Pollen cluster of *Acacia longifolia* with some cells showing marginal shrinkage; c—Fresh pollen cluster of *A longifolia* with no marginal shrinkage; d—Smith's figure of *Phytomorula regularis* Kofoid.

In order to eliminate the possibility of error, the algologist, and especially the one interested in fossil algae, should familiarize himself with as many pollens as possible. Likewise, the pollen analyst should be familiar at least with the various classes of algae.

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NOTES AND RECORDS OF LEPIDOPTERA IN OHIO[1]

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Occasionally southern species of Lepidoptera are found in Southeastern Ohio. The following are records of southern species that have been taken and which seldom reach areas as far north as Ohio.

Erebus odora Linn Jackson, Ohio. 1 ♀—19–V–'37, at filling station; John H. Hughes, Collector.
Errinyis ello Linn. Athens, Ohio. 1♂ 10–VIII–'44, resting on tree trunk; Frederick W. Stehr, Collector.
Errinyis obscura Fabr : Athens, Ohio. 1 ♀—20–IX–'31, in light trap; Wm. C. Stehr, Collector.
Errinyis domingonis Butler: 1 ♀—26–X–'38, on bridge railing; Thatcher Hart, Collector.

From observations on *Asterocampa celtis* (B. & L.) and *Asterocampa clyton* (B. & L.) during the past fifteen years, it appears that in general these species frequent areas of low illumination during the daytime hours. There is some evidence that they may be somewhat crepuscular or even noctufnal in some of their activities. The following records seem to substantiate these conclusions

Of forty specimens of *Asterocampa celtis* (B. & L.) taken between 7:00 A M. and 7:00 P. M. in southeastern Ohio, only two were taken in open sunny areas. All of the others were taken along the edge of woods in rather poorly lighted ravines in Athens, Meigs, Hocking, Jackson, Vinton and Lawrence Counties, Ohio. On July 19, 1938, fourteen specimens of this species were taken along a deep ravine in Torreya State Park, Florida. None were seen in the more open, better lighted areas of the Park.

Of thirty-two specimens of *Asterocampa clyton* (B. & L.) taken during the same period, none were taken in open country. All of them were found in shaded areas.

These species have also been taken occasionally at night. Nocturnal records are herewith presented.

Nocturnal Records of *Asterocampa celtis* (B. & L.).
Athens, Ohio: 1♂, 27–VI–'41, at porch light, 9:45 P. M. Wm. C. Stehr, Coll.
1 ♀, 10–VI–'37, sugaring on tree trunk, 10:00 P. M. Wm. C. Stehr, Coll.
Cherokee, N.C. 1 ♂, 26–VI–'38, at filling station light, 9:30 P. M. Wm. C. Stehr, Coll.

Nocturnal Records of *Asterocampa clyton* (B. & L).
Athens, Ohio: 1 ♂, 4–VII–'31, in light trap. Wm. C. Stehr, Coll.
1 ♀, 3–IX–'33, in light trap. Wm. C. Stehr, Coll.
1 ♂, 6–IX–'33, in light trap. Wm. C. Stehr, Coll.
1 ♂, 1–VII–'32, at light sheet, 10:00 P. M. Wm. C. Stehr, Coll.
1 ♀, 29–VII–'32, at sugar, 11:00 P. M. Wm. C. Stehr, Coll.

In four years, 1931–'34 inclusive, during which a light trap was operated every night from April 15 to October 30, no other species of butterfly was ever taken. Neither were any others ever observed at light sheets, outdoor electric lights or on sugar.

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[1]Paper No. 24, from the Department of Zoology, Ohio University, Athens, Ohio.

A SYSTEMATIC STUDY OF THE MAIN ARTERIES IN THE REGION OF THE HEART—AVES XXI.

PASSERIFORMES—PARIDAE. PART 1[1]

FRED H. GLENNY[2]

As Garrod (1873) has already pointed out, the Passeriformes are characteristically "aves laevo-carotidinae," but as the present writer has shown in several recent papers, in certain orders of birds (Glenny, 1940, 1942 and 1943a, and Glenny, unpublished papers) the arrangement of the internal carotid arteries cannot be entirely utilized as an ordinal character. Furthermore, as has been shown in other recent studies (Glenny, 1943b, 1943a, and 1944) there may be characteristic family variations of the basic ordinal arterial arrangement-pattern within an order—aside from certain minor individual or specific differences—which may be used in gross anatomical and perhaps in phylogenetic studies.

It is of particular interest, therefore, to determine, in so far as possible, the family arrangement-patterns of the main arteries in the neck and thorax of the Passeriformes The present study is limited to a consideration of the arterial arrangements of four species of the Paridae.

MATERIALS

The species used in this study were collected by Professor Tsen-Hwang Shaw, Fan Memorial Institute of Biology, Peiping, China; the Division of Ornithology, Cleveland Museum of Natural History, and the author.

Single specimens of ***Parus major artatus*** (Thayer & Bangs) and ***Parus palustris hellmayri*** (Bianchi), and two specimens of both ***Parus atricapillus*** L and ***Baeolophus bicolor*** L. were dissected and diagrams prepared.

The following observations are based upon the information obtained in the study of the above specimens.

OBSERVATIONS

The basic family arterial arrangement-pattern for the species studied is characteristic

The aortic root (1) arises in the left ventricle, passes anteriorly and diagonally to the right for a short distance before bifurcating to form the innominate arteries (2). The functional (right) systemic (4th aortic) arch (3) arises from the right innominate artery near its base. The systemic arch connects directly with the right radix aortae (4) which passes posteriorly and diagonally from the right toward the centre where it becomes the dorsal aorta (7). The ligamentum aortae (5) remains as an extremely small ligament and the proximal attachment to the pulmonary artery (6) may atrophy completely.

The innominate arteries pass anteriorly and diagonally to the right and left and then divide to form the subclavian (9) and common carotid (8) arteries. The subclavian artery sends off the intercostal (10)—from the posterior face—, coracoid major (11)—from the ventral face—, axillary (12)—from the anterior face—, and two pectoral (13) arteries.

The common carotids give rise to a short thyroid artery (21) before giving rise to the superficial cervical (14), vertebral (15), and internal carotid (18 and 19) arteries. The ductus shawi (16) arises from the vertebral artery, near its origin

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from the common carotid artery, and sends off the syringo-tracheal branches (17) before passing posteriorly to supply the oesophagus, bronchi, and connective tissues in the region of the heart.

The superficial cervical arteries supply the muscles, glands, and accessory tissues of the neck; the right vessel also sends branches to the oesophagus. The right internal carotid becomes functionally modified as the ascending-oesophageal artery (19), while the left internal carotid (trunk) artery (18) alone enters the hypapophysial canal to carry the major cephalic blood supply.

Except in *Baeolophus bicolor*, the scapular arteries arise from the superficial cervical arteries, but in *Baeolophus* the right scapular artery arises from the ascending-oesophageal artery, and the left scapular artery arises from the left vertebral artery or from the left superficial cervical which (in this case) arises from near the base of the left vertebral artery. This may be an individual difference and may vary somewhat in different specimens.

The right ligamentum botalli atrophies completely or fuses entirely with the right radix aortae and is, as a result, entirely lacking.

DISCUSSION

From the above observations it is readily seen that—in so far as the present study is concerned—there is a fundamental and essential similarity in the arrangement of arteries in the neck and thorax of the Paridae. It will be noted further that the species of *Parus* are identical in arrangement, and differ but slightly from *Baeolophus bicolor* in so far as secondary vessels are concerned.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to Professor Tsen-Hwang Shaw, Fan Memorial Institute of Biology, Peiping, China; Dr. E. Horne Craigie, Department of Zoology, University of Toronto, Toronto, Canada; Dr. Harry C. Oberholser, Cleveland Museum of Natural History, Cleveland, Ohio; and Dr. Alexander Wetmore, United States National Museum, for their help and suggestions during the progress of these studies.

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(Unpublished papers):

(a) A systematic study of the main arteries in the region of the heart—Aves XII. Galliformes, Part 1. (In press.)

(b) A systematic study of the main arteries in the region of the heart—Aves XIII. Ciconiiformes, Part 1. (In press.)

(c) A systematic study of the main arteries in the region of the heart—Aves XVII. Colymbiformes, Part 1. (In press.)

(d) The main arteries in the neck and thorax of five species of Parrots.

EXPLANATION OF FIGURES IN PLATE

1, Aortic root; **2**, Innominate arteries; **3**, Right systemic arch; **4**, Radix aortae; **5**, Ligamentum aortae; **6**, Pulmonary artery; **7**, Dorsal aorta; **8**, Common carotid artery; **9**, Subclavian artery; **10**, Intercostal artery; **11**, Coracoid major artery; **12**, Axillary artery; **13**, Pectoral arteries; **14**, Superficial cervical artery; **15**, Vertebral artery; **16**, Ductus shawi; **17**, Syringo-tracheal arteries; **18**, Left internal carotid (trunk) artery; **19**, Ascending-oesophageal (right internal carotid) artery; **20**, Scapular artery; **21**, Thyroid artery.

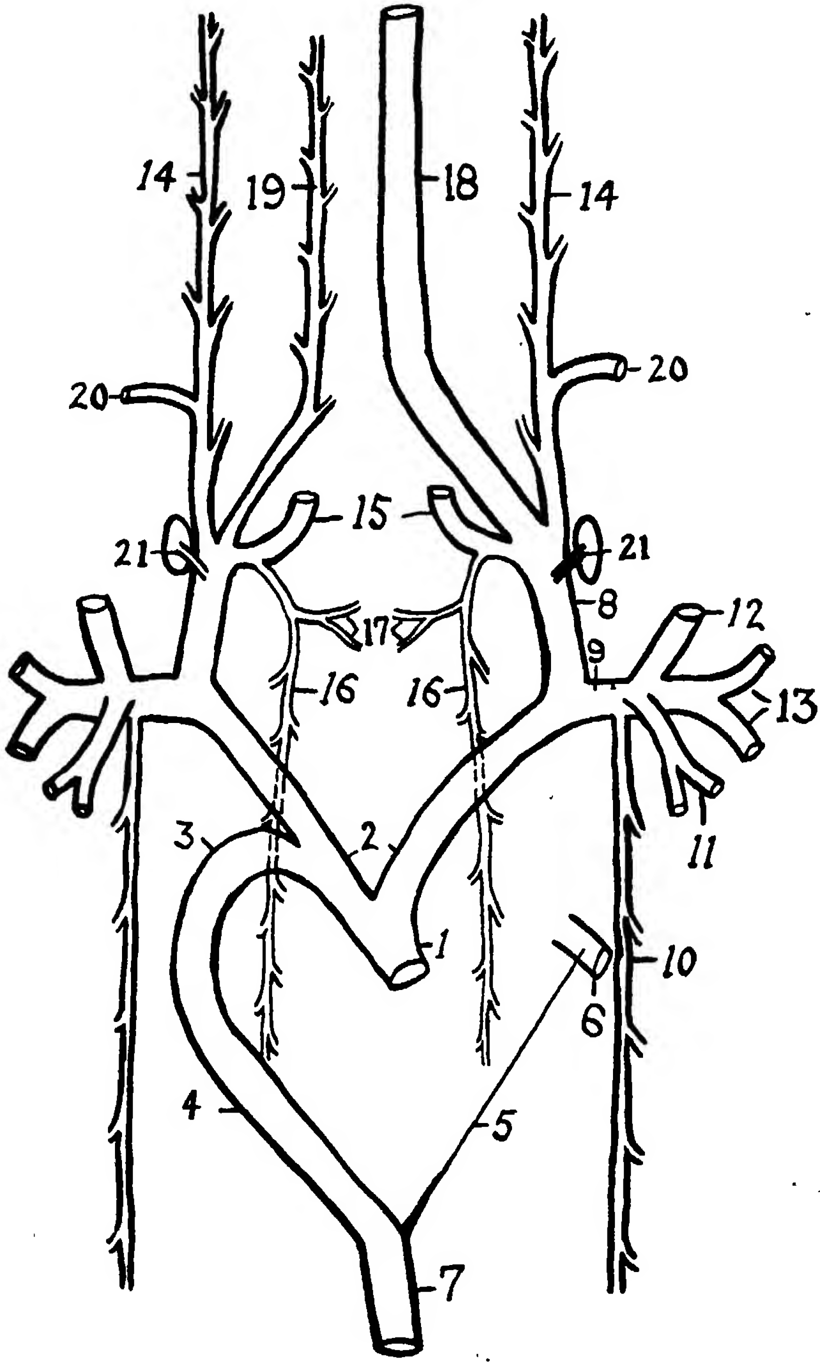

Diagram of the main arteries in the neck and thorax of *Parus palustris hellmayri*. Ventral view.

SOME NEW SPECIES OF CLOANTHANUS (HOMOPTERA-CICADELLIDAE) FROM THE EASTERN UNITED STATES

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Ohio State University

In 1931 Dr. E. D. Ball[1] established several new genera to include species formerly placed under the European genus Platymetopius. The name Scaphytopius was proposed for one group with *Platymetopius elegans* V. D. as the genotype. Another group, Cloanthanus, was established with *Platymetopius angustatus* Osborn as the type. The species for which six generic names were proposed seem to be very similar and it is doubtful if four generic names will prove to be valid genera. *P. elegans* is, however, different from the other species and it seems logical to retain the genus name Scaphytopius for *elegans*. Since *P. angustatus* is designated as the type of Cloanthanus it has been cited here as the genus name for the larger group of related species. Recent work upon the eastern species of this group, using all the available material, and particularly attempting to identify all of the Illinois specimens has indicated several apparently undescribed species on the basis of external characters and the male genital structures.

Several species have previously been confused and placed under the name *P. acutus* Say. In order to establish all of the species concerned it has been necessary to erect a neotype for that species, since the type has been destroyed.

Cloanthanus acutus (Say)

Jassus acutus Say. Jour. Acad. Nat. Sci. Phil. 6: 306, 1831; Compl. Writ. 2: 382.

A pale to dark brown species with yellow, brown margined, face. Length 4.5 mm.

Vertex produced rather sharply, almost two-thirds as wide between eyes at base as median length.

Color: Brown, vertex with median pale vitta at apex and conspicuous pale vittae on disc. Pronotum dark brown, scutellum tawny. Elytra pale with scattered dark brown irrorations leaving many pale spots and areolar spots. Face yellow, heavily infuscated with brown above the white line and at sides.

Genitalia: Female last ventral segment with posterior margin roundedly produced. Male pygofers one-fourth longer than plates. Styles with apical third abruptly narrowed and produced as slender finger-like processes which curve outwardly. Dorsal portion of aedeagus with a long slender ventral process which is sinuate and tapered to apex where it is slightly enlarged. Ventral paired processes long and narrowed to apex. Pygofer long, narrowed to a blunt, produced apex.

This is the common yellow faced species occurring in southern Illinois and Indiana and is undoubtedly the species which Say described. A neotype is erected at this time in order to establish a definite character for future identification. Neotype collected at Greenwood, Wisconsin, August 19, 1916.

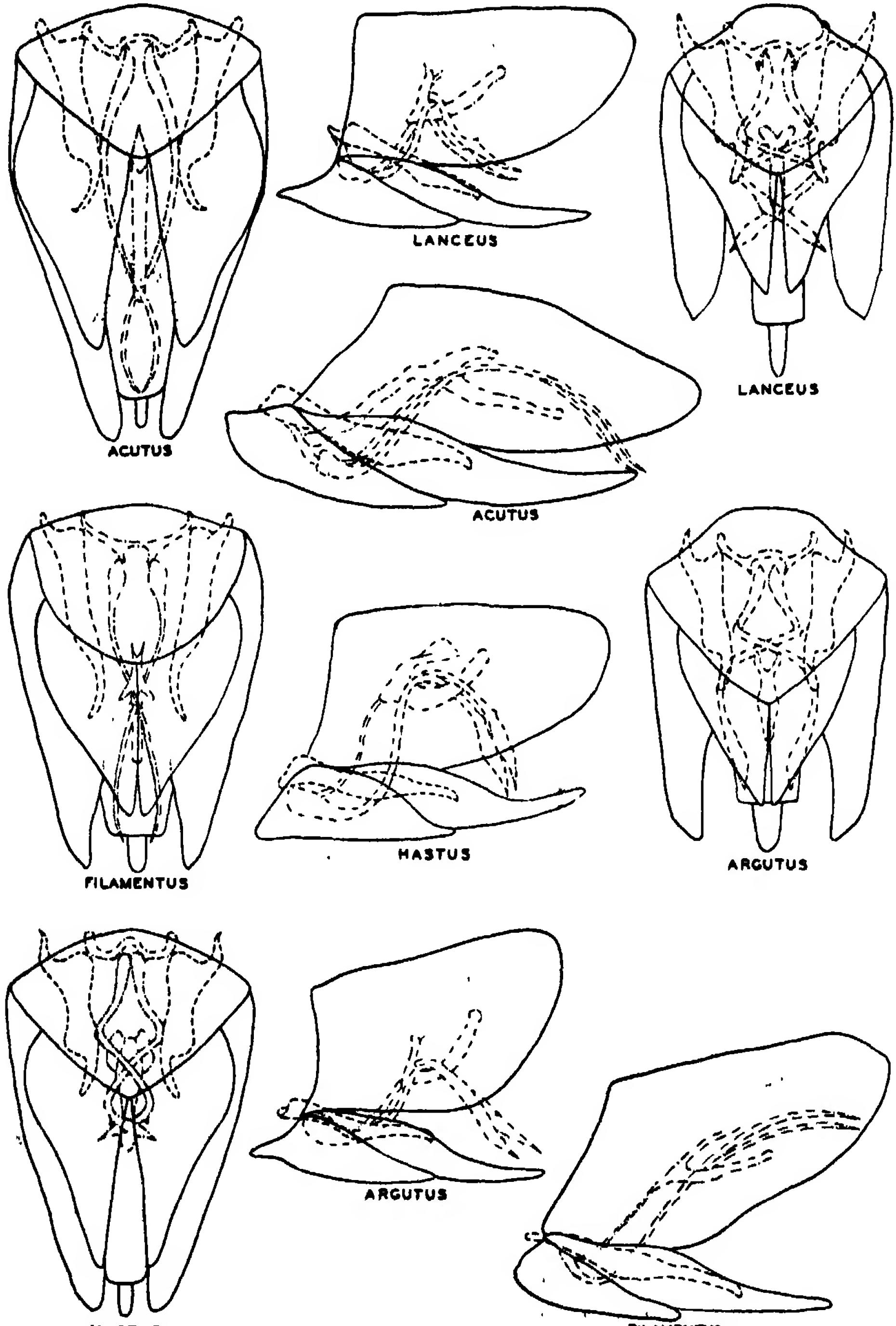
Cloanthanus filamentus n. sp.

Resembling *acutus* in form and general appearance, but paler in color and with a shorter dorsal aedeagus in males and a blunter pygofer. Length 5 mm.

Vertex two-thirds as wide between eyes at base as median length.

Color: Light brown with three pale vittae on apical portion. Pronotum with the usual pale vittae. Apical half of scutellum pale. Elytra rather sparsely irrorate with pale brown so that

[1]Can. Ent., 43: 216–220, 1931.



Ventral and lateral views of male genital structures of species as labelled.

many areolar spots and pale areas are seen throughout the surface. Face yellow with brown margin above.

Genitalia: Female last ventral segment with posterior margin roundedly produced. Male styles narrow, gradually narrowed just beyond middle to narrow curved apical processes which are more than one-third the length of the style. Dorsal portion of aedeagus with an elongated narrow process which is shorter than in *acutus*. Ventral paired processes long, slender, extending almost to apex of pygofer. Pygofer more blunt at apex than *acutus*.

Holotype male and paratype male from Greenville, Pennsylvania, July 14, 1922. Collected by the author.

Types in author's collection.

Cloanthanus tenuis n. sp.

Resembling *acutus* in form and general appearance but with a shorter basally rounded dorsal process of the aedeagus. Length 4.5 mm.

Vertex a little more than half as wide between eyes at base as median length.

Color: Pale brown, vertex with pale longitudinal vittae especially on apical portion of vertex. Pronotum darker on disc, scutellum with apical portion orange yellow Elytra marked with pale brownish irrorations leaving many pale areas and areolar spots. Face yellow with a brown border above.

Genitalia: Male styles with short finger-like processes at apex which are about one-fifth the length of the styles. Dorsal portion of aedeagus medium in length, narrow and with base sharply curved. Ventral paired processes of aedeagus long and slender, reaching to apex of pygofer.

Holotype male, Capa, South Dakota, August 27, 1919 (Severin). Paratype male, Fish Lake, Utah, September 2, 1930, collected by the author.

Types in author's collection.

Cloanthanus hastus n. sp.

Resembling *acutus* in form and general appearance but with a pale brown face Length 4.5 mm.

Vertex elongate, sharply angled, decidedly more than half as wide between eyes at base as median length.

Color: Rather dark brown, vertex with median apical vitta and slender elongate lines pale. Pronotum with five longitudinal vittae. Elytra rather heavily irrorate with brown, veins brown. Many pale areas and areolar spots. Face pale brown.

Genitalia: Female last ventral segment roundedly produced on posterior margin. Male plates almost as long as pygofer, gradually narrowed to blunt apices. Style elongate with an abruptly narrowed finger-like process on inner margin of apex which is almost one-third the length of the style. Aedeagus with the dorsal portion rather short and thickened and bluntly pointed at base. Paired ventral processes long and narrow to apical fifth which is widened to form spear-like blades which are pointed at apex and bear a small spine on the upper surface about one-fourth the distance from apex.

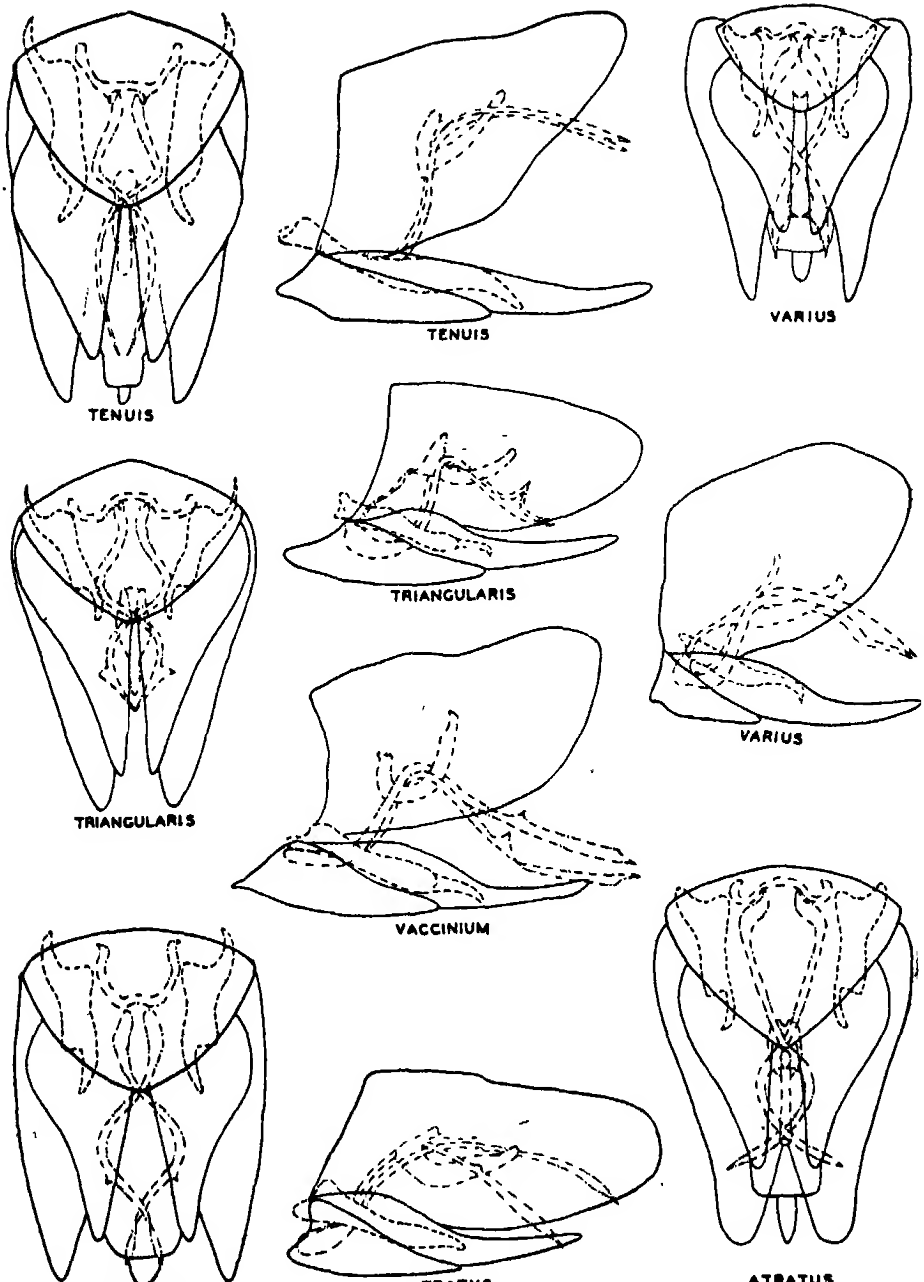
Holotype male, Dixon, Illinois, September 17, 1935; allotype female from Ozark, Illinois, May 18, 1932. Male and female paratypes from same localities and from Cave in Rock, Galena, Centralia, White Pine, Dolson, Mahomet, Des Plaines, Pulaski, Waucanda, Fairfield, Herod, Jeff, Eichorn, Alton, Vienna, and Keithsburg, Illinois; Cranmoor, Wisconsin; Cantwell Cliffs, Ohio; and Neosha, Missouri.

Holotype, allotype and paratypes in Illinois Natural History Survey collection. Paratypes in author's collection.

Cloanthanus argutus n. sp.

In form and general appearance resembling *hastus* but smaller and with distinct male genitalia. Length 4 mm.

Vertex rather sharply angled, a little more than half as wide as median length, one-fourth longer than pronotum.



Ventral and lateral views of male genital structures of species as labelled.

Color: Dark brown with pale markings. Vertex with conspicuous pale longitudinal vittae. Pronotum with several pale punctate spots. Elytra with brown veins and irrorate markings, leaving pale areas throughout and several round pale areolar spots. Face dull yellow below, brown above.

Genitalia: Female last ventral segment roundedly produced on posterior margin. Male plates shorter than pygofer, gradually sloping to bluntly pointed apices. Styles narrowed somewhat at about three-fourths their length, apices rather broad, blunt at apex and produced about one-fourth the length of style. Dorsal portion of style medium in length, a little narrower at apex than base. Ventral paired processes with apical third widened to form a narrow blade which does not bear a spine on dorsal margin. The pygofer is rather broadly rounded at apex.

Holotype male, allotype female and female paratype from Cornelia, Georgia, June 18, 1925. Collected by the author. Type in author's collection.

Cloanthanus lanceus n. sp.

A small sharp headed species resembling *argutus* in general appearance but smaller and with different genitalia. Length 4 mm

Vertex sharply pointed, almost half as wide between eyes at base as median length.

Color: Vertex pale brownish with longitudinal pale markings. Pronotum dark brown with five pale longitudinal vittae. Scutellum paler, apex pale brown. Elytra finely irrorate with dark brown, only a few pale spots visible and with few areolar spots. Face uniform dull yellow to pale brown without infuscation above.

Genitalia: Female last ventral segment roundedly produced on posterior margin. Male style notched on outer margin at about three-fourths its length, forming a finger-like process which is produced to form the apex of the style. Dorsal portion of aedeagus medium in length with a sharp bend at base Ventral paired processes curved through the bend in the dorsal portion, their apices broadened to form blade-like apices which extend about one-fourth the length of process and bear a pointed heel on upper, inner angle of blade ·

Holotype male, allotype female and male and female paratypes collected at Birmingham, Alabama, June 16, 1925, by the author.

Types in author's collection.

Cloanthanus varius n. sp.

Resembling *magdalensis* in form but with vertex white mottled with brown and with distinct male aedeagus. Length 4 mm.

Vertex short, blunt, more than three-fourths as wide between eyes at base as median length.

Color: Vertex white with a marginal bar either side at apex and longitudinal brown vittae at apex and between eyes, giving it a transversely banded appearance. Pronotum dark brown. Scutellum tawny with white spots on median portion. Elytra brown, heavily irrorate with dark brown, mottled appearance of lighter coloration and paler areolar spots. Face heavily irrorate with brown.

Genitalia: Female last ventral segment roundedly produced on posterior margin. Male pygofer decidedly longer than plates. The apical one-third of style narrowed to a slender curved finger-like process. Dorsal portion of aedeagus rather long, constricted just before apex. Ventral paired processes broadened on apical fourth to form a blade. Spine on upper margin about one-third the distance from apex and bent inwardly on dorsal margin.

Holotype male, allotype female and male and female paratypes from Monticello, Illinois, June 11, 1934 (Frison and DeLong). Paratype females, White Pine State Park, July 12, 1934 (DeLong and Ross), Starved Rock, July 14, 1932 (Dozier and Park), Dixon Springs, July 9, 1935 (DeLong and Ross), Marshall, September 27, 1935 (Frison and Ross), Elizabethtown, Illinois, June 25, 1932 (Ross, Dozier and Park).

Holotype, allotype and paratypes in Illinois Natural History Survey collection. Paratypes in author's collection.

Cloanthanus vaccinium n. sp.

A short broad-headed species resembling *magdalensis* but with distinct genitalia. Length 4.5 mm.

Vertex short, three-fourths as wide between eyes at base as median length.

Color: Vertex brown, appearing banded with conspicuous elongate white vittae at middle of apex and base. Elytra dull brown with scattered darker brown irrorations. Veins brown. White areolar spots along commissure of clavus and in base of apical and apex of anteapical cells. Face heavily irrorate with brown.

Genitalia: Female last ventral segment with posterior margin roundedly produced. Male styles abruptly narrowed at two-thirds their length, apical third finger-like and curving slightly outwardly. Dorsal portion of aedeagus broadly curved at base, narrowed on anterior margin at apex. Ventral paired processes with apical third broadened into blade-like portions. A large conspicuous spine on dorsal margin more than one-third the distance from apex.

Holotype male, allotype female and male and female paratypes from Antioch, Illinois, August 24, 1935. Female paratypes from Volo, Grand Detour, and Dixon, Illinois.

Holotype, allotype and paratypes in Illinois Natural History Survey collection. Paratypes in author's collection.

Cloanthanus atratus n. sp.

Form and general appearance of *vaccinium* but with narrower aedeagus blades Length 4 mm.

Vertex about three-fourths as wide at base as median length.

Color: Brown, vertex with few pale markings, a short apical median conspicuous vitta. Elytra brown with brown veins and scattered brown irrorations, leaving many pale areas and white areolar spots. Face heavily irrorate with brown.

Genitalia: Male plates decidedly shorter than pygofer Styles with short narrow apical processes which are about one-fourth the length of style. Dorsal portion of aedeagus broad at base, narrowed on apical fourth. Ventral paired processes with apical third widened to form narrow blades. A small spine is on dorsal margin more than one-third the distance from apex

Holotype male and paratype male collected at Castle Rock, Oregon, Illinois, June 30, 1935 (DeLong and Ross).

Types in Illinois Natural History Survey collection.

Cloanthanus triangularis n sp.

Resembling *magdalensis* but with a more pointed vertex and different male aedeagus. Length 4 mm.

Vertex sharply angled, almost twice as long at middle as basal width between the eyes.

Color: Dark brown with slender pale vittae on vertex. Elytra pale brown, irrorate with darker brown, leaving many pale areas and areolar spots. Veins brown. Face heavily irrorate with brown.

Genitalia: Female last ventral segment with posterior margin roundedly produced. Male plates almost as long as pygofer. Styles with apical third narrowed and produced as finger-like processes. Dorsal portion of aedeagus rather short, narrowed to blunt apex. Ventral paired processes enlarged near apex to form large pointed spines on upper surface which are about one-sixth the distance from apex.

Holotype male, allotype female and male and female paratypes from Shawneetown, Illinois, June 14, 1934 (Ross and DeLong) and June 27, 1934 (DeLong and Mohr).

Holotype, allotype and paratype in Illinois Natural Survey collection. Paratypes in author's collection.

Cloanthanus parvus var. **niger** n. var.

Resembling *parvus* in size and general appearance but with shorter, blunter vertex and darker in color. Length 3.5 mm.

Vertex blunt at apex, two-thirds as wide between eyes at base as median length.

Color: Dark brown, vertex heavily irrorate with a few pale longitudinal markings. Pronotum with five pale vittae. Scutellum paler. Elytra irrorate with brown, leaving many pale spots and white areoles. Face pale brownish.

Genitalia: Female last ventral segment roundedly produced on posterior margin. Male genitalia similar to *parvus*. The dorsal portion of the aedeagus is short and rather thick and is broadly rounded at base. The ventral paired processes are slender throughout.

Holotype male, allotype female and male and female paratypes from Birmingham, Alabama June 16, 1925, collected by the author. In general appearance this appears to be distinct from *parvus*.

Types in author's collection.

BLACK WIDOW SPIDER (LATRODECTUS MACTANS (FABR.)) DISTRIBUTION IN OHIO

SUPPLEMENT

FRANK M. SEMANS,
Entomologist,
North Jackson, Ohio

Since the publication of the original paper[1] a number of new records have been added which increase the total number of Ohio counties in which the black widow spider has been found from thirty-two to thirty-seven. The five additional counties are in the area described in the original paper. The thirty-seven counties are as follows (from Oxford to Youngstown): Butler, Hamilton, Warren, Clermont, Clinton, Brown, Adams, Pickaway, Ross, Pike, Scioto, Ashland, Richland, Knox, Licking, Fairfield, Hocking, Vinton, Jackson, Gallia, Lawrence, Holmes, Coshocton, Muskingum, Perry, Morgan, Athens, Stark, Tuscarawas, Guernsey, Noble, Washington, Carroll, Belmont, Monroe, Columbiana, Mahoning. In the hilly area of Ohio, the counties from which no black widow spiders have been reported are: Highland, Meigs, Harrison, and Jefferson. No new locations have been reported since January, 1942.

[1]Semans, Frank Merrick, 1941, "Black Widow Spider (*Latrodectus mactans* Fab.) Distribution in Ohio," O. Jour. Sci., 41: 380, 1941.

Chandler's Parasitology

This new edition of a well known textbook contains an amazing amount of new information and the publisher's announcement of a completely rewritten book is entirely justified. At first glance, however, it looks much like its predecessors due to the fact that the illustrations are the same and many introductory remarks are identical with previous editions. Careful reading reveals that Doctor Chandler has thoroughly covered and appraised recent literature and his labors make the tasks of teachers and research workers easier.

The new size due to smaller margins and thinner paper, we hope, will continue in future editions which will appear after all thoughts of the present paper shortage have passed.

—*C. E. Venard.*

Introduction to parasitology with special reference to the parasites of man, by Asa C. Chandler. x+716 pages, 309 illustrations, 7th edition. 1944. Price $5.00.

REVIEW PAPERS

(Papers appearing in this section are invited reviews of subjects of wide current interest.)

FUELING A GLOBAL WAR[1]

An Adventure in Statecraft

MAX W. BALL,
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Petroleum Administration for War,
Washington 25, D. C.

My story is a story of the American spirit in action. My theme is a unique adventure in statecraft. My example is a form of government-industry cooperation that has made possible the impossible. Specifically, my example is the fueling and lubricating of the greatest armament the world has ever seen: more planes than ever before swept the skies; more vehicles and armor than ever before roamed the land; more ships than ever before ploughed the seas; more landing craft than ever crawled ashore. The story is one of grueling effort and hard-won success; of achievement through a new form of industry-government teamwork.

THE VITAL MUNITION

Napoleon once remarked that "an army marches on its stomach." Today an army marches—and a navy sails and an airplane flies—on its fuel tanks. More than 65 per cent of all the tonnage shipped overseas is liquid fuel—gasoline, diesel fuel, and fuel oil. Think that over for a moment: The oil required to fuel and support our armament is nearly double the tonnage of the armament itself, the shells and cartridges for the guns, the food, shelter, medical supplies, and creature comforts for the men, the repair parts and replacements for the equipment, and all other supplies.

ARMAMENT WITHOUT OIL

What good would all our armament be without fuel and lubricants? None whatever. Deprived of mobility it would be just so much scrap, useful only on the salvage dump. Without gasoline, a fair-grounds balloon is better than an airplane, and a bicycle than the fleetest staff car built. Without fuel oil a Chinese junk is a better craft than the mightiest battleship. Without lubricants, no plane or gun or tank or car or ship could move through even the shortest campaign. Equipment without fuel and lubricants is as bad as a rifle without cartridges; a good stout club is a better weapon.

MILITARY USE

I am not free to give you figures on the total quantities of the various oil products required, but I can give you a few comparisons, from which you can do your own addition and multiplication. A tank car load of gasoline would

[1]John Adams Bownocker Memorial Lecture given January 16, 1945, through cooperation of the Bownocker Fund, Department of Geology, the Ohio State University, and the Ohio State Chapter of the Society of Sigma Xi.

fill the ordinary civilian's car for nearly 14 peacetime years, but it will fill the tanks of a B-29 only once. Aviation gasoline consumption has increased by more than 1,000 per cent since Pearl Harbor.

Present aviation gasoline requirements for our air forces are 14 times the total gasoline for all purposes shipped to Europe at the height of the last war. Our air forces alone are using more gasoline per day than all the trucks and buses in the United States. If these are the requirements of the air, try to compute the gasoline and diesel fuel consumed by ground equipment—tanks, trucks, tractors, guns, armored cars, jeeps, and all the rest—in western Europe alone. Then add Italy and the Pacific area and the rest of the fronts, and the supply areas back of the fronts. The Navy, which operates on the sea, has more than 140,000 vehicles operating on land. Try to imagine, then, how many the Army must have! When that gets beyond your grasp, stupefy your imagination by thinking how much fuel oil is consumed by the ships of the Navy, Coast Guard, and the merchant fleet, operating on the seven seas. It is greater than the entire marine fuel consumption of the world a few short years ago.

At every beat of your heart enough oil goes overseas to run a car from Fairbanks, Alaska, across Canada, the United States, and Mexico nearly to Central America. Military use and overseas shipments in 1944 would have buried the whole of Manhattan Island under nearly four feet of oil.

ESSENTIAL DOMESTIC USE

Then, when you think you have an adequate conception of overseas and offshore requirements, add essential domestic consumption. War plants and plants making essential goods must run; many of them run on fuel oil or natural gas; all of them require lubricants. Houses and offices and apartment buildings and hotels must be heated; many of them are equipped to burn nothing but oil, and no other equipment can be had. Unless farm tractors and trucks were supplied with gas and oil the production of food would decrease alarmingly. Diesel and oil-burning locomotives must run; otherwise the railroads would face an even greater problem than they do. Unless cross-country buses and trucks can run, the task of the railroads would become impossible and many communities would be marooned without transportation. Unless urban buses and trucks can run, workers could not get to and from their jobs, food and supplies could not be distributed, and the productive activities of our cities would soon be demoralized. Without gasoline hundreds of thousands of workers could not get to their jobs and thousands of executives and professional men could not go about their necessary businesses. Even the ordinary civilian needs to drive a few miles now and then; his pattern of living was designed on gasoline.

Rationing of gasoline and fuel oil, conversion to other fuels and other conservation measures have somewhat curtailed civilian consumption—otherwise military demands could not have been met—but the curtailment has been largely offset by the needs of a vastly expanded war industry. Civilian consumption is considerably below its volume before Pearl Harbor, but is still about two and a half times military consumption. In an industrialized nation, the home front requires even more oil than the fighting fronts.

ALLIED AND NEUTRAL NATIONS

That still is not all. We are not fighting this war alone, thank God, on either the fighting or the production fronts. The armies, the navies, and the air forces of our fighting allies must be supplied with fuel. Their industries and their essential civilian uses must be supplied as well. The civilian economies of liberated areas must be restored as rapidly as possible, for military and productive as well as humanitarian reasons, and oil products bear a large part in the restoration.

It should be said, in passing, that the civilian economies of our allies and of

neutral and liberated nations have not been supplied with anything like the generosity accorded to our own. It has been years since an English civilian, for example, could drive his car to market for the week's groceries or meet a baggage-laden friend at the station.

Except for Russia, most of these oil products must perforce come from the United States. The fields of Latin America and the Middle East are being utilized to the limit of available refining and transportation facilities. Their facilities and output have been and are being expanded as rapidly as time, distance, and availability of materials permit; faster, proportionately, than those in this country. Nevertheless, the producing and refining facilities of the United States must still carry most of the burden. To our own military and domestic consumption, then, must be added a good share of the military and essential civilian consumption of the allied, neutral, and liberated countries.

THE MULTITUDE OF PRODUCTS

The staggering quantities are only half the story. The job is as complex as it is stupendous Jeeps won't run on diesel fuel or tanks on heavy fuel oil or battleships on gasoline. Planes would be sitting ducks for the enemy if fueled with motor gasoline. Carriers and PT boats don't use the same fuel. The oil that heats an apartment house would not run your car or fuel an industrial plant. Diesel trucks and buses can't use gasoline, and the fuel for diesel locomotives differs from that for diesel trucks and buses As for lubricants, their variety is bewildering. Motor oil for jeeps won't do for the engines in a carrier. The turbines in a battleship require different lubricants than the generators or the gun turrets or the recoil mechanisms or the ammunition hoists. A B-29 uses 26 different oil products and derivatives. The number of different oil products used in essential industries is too great to enumerate.

Someone has said that winning a war is a matter of having enough of the right things at the right places at the right time, but enough oil to the right place at the right time is no good unless the oil is of the right kind. Each petroleum product, whether aviation gasoline, heavy fuel oil. Arctic motor oil, or axle grease, must be tailor-made for its particular use; it must be made in the right quantities; and it must be where it is needed, when it is needed. Time, place, quantity, *and kind* are the essential elements.

CRUDE OILS AND REFINERIES

Can you visualize the job of meeting these requirements? There are almost as many different kinds of crude oil as there are major oil fields. Some crudes are well adapted to making aviation fuel, some are not. Some are high in total gasoline yield, some are low. Some yield excellent lubricants, others do not Some make more and better diesel fuel than others. Some are most notable for their heavy fuel oil yields.

Moreover, no crude oil is converted wholly into a single product such as gasoline or fuel oil or lubricants. Every crude yields from a half dozen to a half hundred or more products, the number, quantity, and quality of each depending partly on the character of the crude and partly on the refining processes to which it is subjected.

These refining processes are in themselves numerous and complex, and the units in which they are carried out are adapted to only one general type of operation. Refinery equipment is not ordered out of stock in standard shapes and sizes. Each piece is individually designed and built to produce certain products out of a certain raw material. A plant built to make maximum motor gasoline from East Texas crude cannot be converted overnight to make maximum lubricating stock from Gulf Coast crude; a large part of it would have to be redesigned and rebuilt, and after the change was made its secondary products—furnace oil, diesel

fuel, heavy fuels, and the rest—might be entirely different from what it made before.

Every one of the secondary products from every plant is important, for the secondary product of a plant is the primary fuel or lubricant in some specific use. It follows that if the right product is to be at the right place at the right time in the right quantity, the right crude must be processed in the right refinery, far enough in advance to permit delivery where needed when needed.

To produce the crude oil in the respective fields, get each grade to the refineries best fitted to use it, make the needed products, and distribute the products to the points of use requires a far-flung inter-related system of wells, refineries, pipe lines, tankers, tank barges, tank cars, tank trucks, terminals, ports, and loading facilities, each part of which must be correlated with the rest of the system. Supplying the world with oil, even in peace time, is a complex business.

WARTIME COMPLICATIONS

Into this already complex business the war has introduced endless new complications. Millions of barrels of new products have been required, specifications for old products have been changed, increased yields of some products have been demanded and decreased yields of others, and the relative demand for each product has changed from month to month. The needs of individual refineries for crudes of particular characteristics have shifted. The supply of some crudes has diminished and of others has increased.

Many tankers depended on to carry crude from the fields to the refineries have been sunk by the enemy or diverted to carrying products overseas. Overland transportation by pipe line, tank car, tank truck, and barge has had to replace coastwise and lake shipping. New pipe lines have had to be built and old ones relaid or reversed. Terminal and loading facilities have had to be pooled. The entire oil transportation system east of the Rockies has had to be revamped, one of the most intricate transportation systems in the world, built up through more than 50 years of trial and error.

Shortages of materials and men have imposed further difficulties. The oil business uses huge tonnages of steel, copper, lead, and other metals, great quantities of chemicals, thousands of specialized geologists, chemists, and engineers, and hundreds of thousands of highly-skilled workmen.

Called on for a great expansion of output, it would normally have increased its use of both materials and men. Yet both materials and men have been needed by the armed services and by other essential industries. Greatly increased output of petroleum products has therefore had to be achieved with a decreased amount of materials and fewer men. Fueling and lubricating a global war wouldn't be half so tough if it didn't have to be done in wartime.

ONLY THE INDUSTRY COULD DO IT

Have I succeeded in giving you a conception of the magnitude and complexity of the job? Five years ago almost any oil man would have declared the task impossible. No informed person who could have foreseen the needs would have believed that the petroleum industry could supply them. Yet the petroleum industry is doing it. No one else could possibly do it. Only an industry with a pre-war total initial investment of 15 billion dollars, the second largest industry in the United States, could think of doing it. Before the war the industry was accustomed to producing and refining upwards of three million barrels of oil per day, and delivering the products to cross roads and main street intersections, from coast to coast and border to border. Only an industry with the competence, the technical skill, the adaptability, and the ingenuity to carry on such far-flung, complex, and constantly changing operations as a daily routine—only such an industry would have known how to start. That fact is obvious. A second fact

is almost as obvious: Although the industry alone could do the job, it could not do the job alone, for a number of reasons. In the first place, it lacked the necessary coherence and centralization; it was too competitive.

THE COMPETITIVE SPIRIT

Those of you who still think of the oil business as a monopoly, an octopus with one head and many tentacles, are about thirty years behind the times. Those filling stations at cross roads and street intersections cost money, plenty of money. Would a monopoly have built them to get your business? A monopoly would get your business without such expenditures; you might not like to go five miles instead of five blocks to get your gasoline, but you would do it—and use more gasoline in the doing. Would a monopoly have cut the price of tax-free gasoline in two from 1920 to 1938? The oil business did. Would a monopoly have increased the average octane rating of your gasoline by 10 points in the same period while it was cutting the price in half? The oil business did. The idea that the oil business is a monopoly is as out of date as button shoes and hobble skirts.

Those filling stations, the improved quality represented by those extra octane numbers, and those price cuts have come about because thousands of producers, refiners, and marketers, big and little, are each trying to get more business and keep it. The oil man's creed about additional business is simple: Find it, create it, develop it, or take it, but get it. An oil man scarcely dares to take a nap, lest some competitor discover a new field or develop a new process or tie up a market that he could have had if he had stayed awake. If there is an industry more competitive than the oil business, count me out of it.

Now all this competition is a grand thing in time of peace. It means higher quality, lower prices, better service, millions of dollars a year spent in research, technologic advancement so rapid that a plant may be obsolete by the time it is completed, all of which redounds to the public good. It may also be a grand thing in time of war, provided that competitive practices do not interfere with a coherent, unified, one-for-all effort to do an all-out emergency job.

Unfortunately, some competitive patterns do just that. A producer who has a surplus of drilling rigs doesn't ordinarily turn them over to his neighbor who may have none, yet it may be important to the war effort that the neighbor's lease be drilled. A refiner who has contracted for a crude supply doesn't normally divert part to his competitor, even though the competitor's plant might make more 100-octane gasoline from it. A marketer with excess terminal capacity doesn't usually invite his competitors to use the excess. A company that has spent a million dollars developing a process to make better gasoline at lower cost isn't likely to throw it open for the world to use. Yet some of these things were bound to be necessary. Could and would oil men forego competitive practices so far as required for the common good?

GUIDANCE AND PROTECTION NECESSARY

Suppose they did? Suppose that every man in the oil business could lay his ingrained competitive instincts completely on the altar of the war effort, who would tell him how to make his sacrifice, where his tools or his crude oil were most urgently needed, what competitors would make the best use of his processes or his excess facilities? Who would tell him how much to give and to whom? Most important of all, who would protect him from fine and imprisonment for doing things that in war are called cooperation but in peace are called collusion? Oil men hesitate to lunch with a competitor, for fear of an anti-trust investigation.

Moreover, who would protect the industry from its own sharp-shooters, those who might refuse to cooperate, who might knife a competitor behind the screen of war activity? Such sharpshooters would be few and under normal conditions unimportant, but one small monkey wrench can wreck a big machine, when the machine is running at the speed the oil industry would have to maintain.

WHO WOULD PLAN AND PROGRAM

Second, if the industry were to attempt the job alone, who would plan and program it? Who would coordinate the productive efforts of thousands of producing, refining, transportation, and marketing companies to meet the needs of a dozen armed services and a score of civilian economies? Who would analyze and predict the needs of our own armed services, merchant marine, and civilian economy, those of our allies, and the civilian economies of the neutral and liberated countries? Who, when such a program of needs had been drawn for as far ahead as might be, would determine how much of which product should come from where, in order that the needs might be met?

If the tremendous needs of the war were to be met with the limited materials and men available, the output of every well, every natural gasoline plant, every refinery and every unit in every refinery, would have to go to the plant, the port, or the consumer where it would do the most good. The transportation of every barrel would have to be planned so that tanker space, always in short supply and subject to enemy action, might be utilized to the best advantage and wherever possible be replaced by overland transportation To save transportation, supplies for each point of use should be lifted from the nearest available source, a matter that in itself would require far-sighted programming.

Such planning must not only cut across all competitive lines, it must be world-wide in its scope, cutting across all international boundaries. Here clearly was a task beyond the capacities of a vast but competitive industry.

WHO WOULD DEAL WITH FOREIGN POWERS

Even though the industry could legally achieve a degree of unity enabling it to disregard competitive boundaries, it could not without governmental powers disregard international boundaries Only an agency of government could deal with allied and neutral governments, gathering the information, conducting the negotiations, and doing, with them, the world-wide planning necessary to success.

WHO WOULD DEAL WITH DOMESTIC AGENCIES

Who, for that matter, would deal with the numerous agencies of our own government that in wartime perforce have some connection with the oil effort? There are thirty to forty of them—I have not taken time to count them—including the Geological Survey, the Bureau of Mines, various bureaus of the Treasury Department, the Department of Justice, the Interstate Commerce Commission, the Office of Defense Transportation, Defense Plant Corporation, Defense Supplies Corporation, the War Manpower Commission, the Office of Price Administration, the War Production Board, and a host of others. With the necessary wartime concern of these agencies in his business, an oil man would almost have to spend his full time in Washington, with a retinue of guides and special representatives, if he had to deal directly with all of them.

If his war effort were to be effective, there must be an agency with which he could deal, and with which alone he need deal except as it took him to other agencies.

WHO WOULD OBTAIN THE MATERIALS

Finally, in wartime Washington with its vital control over vital materials, who would get the industry the materials for its wartime needs?

The industry requires iron and steel and copper in large quantities. It requires pipe and pumps and valves and compressors and engines and trucks and instruments. It requires tires and hose and rubber tubing. It cannot function without tankers and tank cars and tank barges and tank trucks. It uses chemicals and lots of them. It requires a hundred other things. The oil business is not only a huge producer; it is also a voracious consumer. How, in an ever-tightening market, would it get the diet of materials it would have to have?

Most of the materials were in limited supply. Already the government had set up agencies to apportion the available quantities where they would do the most good. If a half million producers and refiners and distributors should descend upon the agencies, each clamoring for what he wanted, would each of them get what he should have and only what he should have for his war effort? Would the industry as a whole get what it should have? Would the limited supply that could be allocated to the oil business be placed where it was most urgently needed? Obviously not. Someone who knew the problems and the needs of the business as a whole would have to screen and consolidate the applications, then press the industry's claim for enough materials for its job, and then see that they were efficiently used where they would do the most wartime good. There would have to be what Washington has come to call a "claimant agency."

THE GOVERNMENT MUST PROVIDE AN AGENCY

No, the industry as such could not do the war job alone; there must be an agency to guide, coordinate, and where necessary direct the effort, to represent the war-conceived necessities of the industry, to deal with foreign governments, and, in conjunction with them, to plan the worldwide program that the industry would carry out. The government itself, through an agency created for the purpose, must guide, coordinate, direct, and represent.

Thus, inescapably, the Office of Petroleum Coordinator was established on May 28, 1941, with Secretary of the Interior Ickes as Coordinator, and on December 2, 1942, this was changed to the present Petroleum Administration for War, PAW for short, with Mr. Ickes as Administrator.

OPERATION OR COOPERATION

At the outset, a vital decision had to be made: Should the government take over and operate the industry? There were men who thought that only through government operation could competition be subdued into cooperation, could the know-how of the industry and the authority of the government be brought together. There were men who believed in government ownership in peace as well as war, and who thought this an opportunity that should not be missed. There may even have been men—little men—whose fingers itched for the giant authority that government operation might give them. Advocates of government operation were not wanting.

Mr. Ickes, however, had a greater vision, a plan by which the industry and the government should go to work together. The tremendous strength of the industry, the vigor and virility bred into it by competition, should be kept unimpaired and be utilized to the full in the mightest war effort man had ever seen. From the industry's great store of talent should be drawn in large part the government organization to aid and guide and administer the effort. Teamwork between the two should be assured by industry committees working intimately with the administrative units. Thus closely integrated, each doing the part that it alone could do, industry and government would do the job together. Whether we may think as much of Mr. Ickes as Mr. Roosevelt has shown that he does, or as little as Mr. Dewey, for example, has said that he does, one fact is clear: his handling of the oil situation during the war has been that of a great statesman.

STAFFING THE AGENCY

His first act was to pick as Deputy Petroleum Administrator, to run the job, an outstanding oil company executive, the type who combines administrative force with vision and public spirit, Ralph K. Davies, executive vice-president of Standard of California.

Some men would have been hesitant lest they be accused of favoritism or would have been fearful that oil men might grind private axes in public positions.

Mr. Ickes had more faith in human nature. He encouraged Mr. Davies to staff from top to bottom with men who knew oil and the oil business, drawn chiefly from the industry, with a leaven of such men from government technical bureaus, state agencies, and educational institutions as were qualified and available.

To assure breadth of knowledge and balanced point of view, the men were drawn from all branches and phases of the industry, from such related industries as the construction and supply companies, from all parts of the country, and from big and little companies alike. The great major companies and the small but vital independents were evenly represented so far as possible. For fairness and impartiality, reliance was placed on the integrity and patriotism of the men selected and their diversity of background. No man passes on any matter that deals with the company with which he was formerly connected. If anyone did attempt to favor a former affiliation, it would most certainly be caught by some one of the other men through whose hands it must pass, men with different former affiliations. These precautions have proved notably unnecessary. An able and unselfish executive who spent three years in PAW, and left recently to go back to the industry, remarked on leaving that he had not seen a single attempt by any PAW man to favor his former company. After all, these are high-type men; such men are prone to intensive singleness of purpose; and the purpose of all of them is to win the war.

POLITICS AND ECONOMICS

Political affiliation and economic views, likewise, were to be neither asked nor considered in staffing the organization; men were to be selected for their knowledge and ability, not their politics.

I have spoken in the past tense, but what was true at the start is true today. I am a newcomer in the organization. I doubt that Mr. Ickes agrees with some of my published views on planned economy, but that did not prevent my being drafted for service. No one has asked me whether, in the last four presidential elections, I have voted for one man or for four; so far as PAW is concerned, no one cares. Almost any day, in the executives' lunch room, you can hear a rampant Republican, or a half dozen, staging an argument with some equally rampant New Dealer, openly and fearlessly, or a disciple of Adam Smith battling with a disciple of Stuart Chase. But the politics and the economic theories are left in the lunch room, along with the tips and the paper napkins. They have no part in what goes on in the offices upstairs.

THE TEAM-WORK IDEA

Mr. Ickes' next step, after appointing Mr. Davies, was to call representatives of the industry together and explain his plan and his purpose. He emphasized that the spirit of both plan and purpose was cooperation rather than coercion. The oil men listened politely, then went home to tidy up their bomb-proof shelters. These men, you must remember, had been listening for ten years to proposals from Washington, ranging from making the oil business a public utility to expropriating it. Small wonder that they were skeptical.

Skepticism lessened, however, when the plan began to function, and the industry discovered that it was a full-time working partner, participating fully in the partnership business and in the partnership councils.

CONTACT WITH THE INDUSTRY

One of the first things to reassure it was the dispersion of the organization into intimate contact with the industry, instead of its concentration in cloistered halls in Washington. Mr. Davies decentralized his staff; got as many of his men as practicable out into district offices, where the derricks and refineries and bulk stations are. An oil operator no longer had to go to Washington to present his needs or views; consideration was given on the spot by men trained in the

operator's special branch or function of the industry. Each district office had a staff trained in each function of the business: production, natural gas and natural gasoline, refining, transportation, and distribution.

In Washington each function of the business was represented by a division headed and staffed by specialists in that function. The staff included men with established reputations as geologists, drillers, production engineers, field superintendents, pipe line builders and operators, refinery engineers, chemists, refinery superintendents, research men, sales managers, traffic men, station managers, economists, lawyers, accountants, and all the other specialties that go to make up the vast and complex organism of the oil business. The industry found its needs and its problems in the hands of men who knew them and whom the industry knew.

KEEPING THE COOPERATIVE ATTITUDE

Even an organization drawn largely from the industry, however, might lose the cooperative touch if allowed to set itself apart. The possession of authority is a great temptation to use it unsparingly. Coercion is often simpler than cooperation. Arbitrary decisions are more quickly and easily reached than joint decisions. Autocracy, on the surface, looks more efficient than democracy. Men might be pardoned for thinking the fastest and cheapest way to get the job done would be for PAW to decide what the industry needed, tell the industry what to do, and let the industry then go and do it.

To their credit be it said that few men in PAW were inclined to this easy but dangerous fallacy, and they were soon set right. The men at the top knew better; so did virtually all the men in the ranks. The job was too big to be directed by a few men temporarily vested with authority. The problems of the war effort were too great to be analyzed and solved, unaided, by a government agency.

The key lay in working together. PAW must not become the autocrat, industry the menial. The relationship should always be one of partnership.

How establish and maintain that relationship? How counteract the natural tendency of government bureaus to become autocratic, and of industry to look with hostility on government guidance? How make the effort a joint effort, putting behind it all the brains and vigor of the industry, all the power and knowledge of the government? Mr. Ickes and Mr. Davies had the answer; the right answer, as time has proved.

THE INDUSTRY COMMITTEES

In each of PAW'S districts industry committees were formed, one for each functional division of the industry: production, natural gas and natural gasoline, refining, supply and transportation, distribution and marketing. These committees work with the corresponding PAW functional directors, district and national; the production committee, for example, with the district and national directors of production. The chairmen of the five functional committees, with a chairman chosen for his grasp of all the functions in the district, constitute a district general committee, working with PAW on matters affecting all branches of the business in the district. Both the general and the functional committees may have special committees and subcommittees performing specific duties or dealing with special problems, such as committees on manpower, construction, materials, technical data, research, and the like; whatever needs to be covered, these district committees cover. Most of them have paid staffs; some of them have full-time executives. They bear all the costs of their own work, and a great many of the members give more time to their committee work than to their company duties.

Note how these committees differ from the industry advisory committees attached to so many government bodies. They are not window dressing, existing to give occasional advice and to create an illusion of cooperation. They are

working bodies. They are advisory in the sense that they have no power to issue orders, but it is a rare district order that is not in accord with their judgment. They supply most of the facts on which action is based. If more facts are needed, they find them and analyze them. On the one hand they recommend actions to be taken; on the other they explain to their associates in industry the reasons for the actions. They work out solutions to the multitude of problems that arise. They carry out approved programs. Many of the ablest executives in the oil business serve on these committees, and some of them have given their full time to the administration of programs of particular difficulty, programs that averted disaster through their patriotic efforts.

These committees are a far cry from the purely advisory committees of other days and other agencies, useful as some of them may have been.

SELECTING THE COMMITTEES

How were the committees selected? Mr. Ickes and Mr. Davies asked the industry to submit nominations. Anyone in or connected with the industry could submit as many names as he chose. The industry responded with thousands of nominations, naming several hundred men. From these the committees were appointed, care being taken that on each should be balanced representation between the major and the independent companies, big and little, and that all points of view should be represented.

As thus constituted the committees represent an impartial working cross-section of the best talent in each district.

More than 1,000 men serve on these committees; 1,000 picked men of the industry, whose willing services could not be had in any other way.

THE PETROLEUM INDUSTRY WAR COUNCIL

The cooperation I have so far described is at the district level, but the plan does not stop there; it extends to the top. The industry body which deals with matters of national scope, and through which the industry's entire effort is unified, is the Petroleum Industry War Council, PIWC for short, made up of 78 top-flight industry executives.

The Council is composed of, first, the chairmen of the district general and functional committees; second, the heads of the nineteen trade associations in or dependent on the industry; third, outstanding company executives, both major and independent, who happen not to be included in one of the other categories; and fourth, ex-officio, the chairman of the Foreign Operations Committee, of which more anon.

The Council too has its committees, a long list of them, covering the same functional activities as the district functional committees and a number of other things such as conservation, economics, renegotiation, disposition of government-financed facilities, and national oil policy. These committees draw upon the entire knowledge of the industry as well as the knowledge of PAW, they confer with the appropriate PAW divisions, and they report to the Council or to PAW through the Council.

The Council meets regularly with the chief executives of PAW, and at these meetings all the major problems and policies of the *worldwide oil situation* are on the table. The Council, working with the executives of PAW, is the powerhouse of industry-government cooperation.

GLOBAL ATTENTION

Notice that phrase, "the worldwide oil situation." The functions of PAW do not stop at the water's edge; the cooperation of the industry is not circumscribed by our national boundaries. Every gallon of petroleum products produced or used by the United Nations anywhere in the world is within the sphere of interest and activity.

PAW's studies of problems and supplies outside the United States are carried out by three foreign divisions headquartered in Washington, devoted respectively to foreign production, foreign refining, and foreign supply and distribution. The corresponding industry body is the Foreign Operations Committee.

The Foreign Operations Committee is to the foreign situation what the Petroleum Industry War Council is to the domestic situation. It too has numerous committees, functional and geographic, working on every phase of foreign production, refining, transportation, and distribution, as intensively and devotedly as the committees working on domestic problems.

PAW's foreign divisions also cooperate closely with foreign governments and with agencies of our government concerned in foreign affairs, particularly, as to the latter, with the State Department, the Foreign Economic Administration, and the armed services. Great Britain is represented in Washington by a British Petroleum Representative. Without whole-hearted British cooperation much of the effectiveness of the worldwide effort would have been lost. Canada's Oil Controller has a representative in the PAW building. Other governments either have oil representatives in Washington or keep in touch through their embassy staffs or their home offices.

Thus the world is covered, and many interesting as well as important things are given attention: Facilities for making 100-octane gasoline in the Dutch West Indies or on the Persian Gulf; multiplying the amount of oil coming out of the Caribbean region; providing additional refining facilities for Russia and for Saudi Arabia; possible utilization of liberated refineries that the Germans left too fast to wreck—these are samples of the things considered. The petroleum problems of a global war are studied under a global microscope and solved by global cooperation.

HOW IT WORKS

If all this seems complex and confusing it is only because the business to be done is of infinite variety. In practice the operation is direct and efficient. Let's take an illustration, hypothetical and simpler than most problems:

One fine morning the Army calls up PAW and says that after a certain date it will need an increased monthly supply of a certain special lubricant. The directors of PAW'S divisions of production, refining, supply and transportation, distribution, materials, and program get together and if necessary get in touch with their respective district directors and the industry committees concerned. The matter may be taken up in the domestic operating committee, for consideration whether the demand can be met by decreasing some civilian use, whether transportation can be made available to deliver the product where the Army wants it, whether the program for other products would be thrown out of gear. The foreign divisions may be consulted to see whether an overseas source, closer to the point of use, could be developed. At length, and more quickly than you might think, a decision is reached that the special oil can best be made, with minimum disturbance of the output of other essential products, by Gulf Coast refineries using a certain grade of Texas crude. The directors of production and refining notify their respective district directors at Houston. The district director of refining lays the problem before the district refining committee and together they decide that plants A, B, and C at Houston and Beaumont can best do the job. After consulting with the plant managements they find that plants B and C will need certain additional equipment and half a dozen skilled men to install it, and that the new installation at plant B will have to be financed by the government. The plants prepare for the necessary change-over and the district office informs Washington of the materials, manpower, and money needed.

Meanwhile the district director of production has met with the district production committee and arrangements have been made for the diversion to plants A, B, and C of the necessary supply of the desired grade of crude. He too reports his results to Washington.

In Washington the request for materials, men, and money gets immediate attention. The director of the materials division, after studying his own files and perhaps those of two or three other government agencies, and discussing the matter with the PAW construction officer, decides that plants M and N at Pittsburgh and Gary can supply the requisite sheets and shapes of special steel, and that plants X and Y at Marietta and Terre Haute can fabricate them into the necessary pressure stills without undue delay to other urgent war orders. Then he asks the War Production Board to allocate the necessary critical materials. With the support of the Army, he convinces them that the need is great enough to warrant the allocation, even though the materials must be taken from the tank or some other urgent program.

The critical materials are allocated and the production and fabrication of the steel are given a high priority, high enough to insure plants M, N, X, and Y of being able to make delivery in time. The director of materials sees that the orders are placed and manufacture started. Then his men keep a constant check on the plants until the orders are completed and shipped, and he keeps plants B and C informed of progress.

While thus engaged the director of refining has taken up the matter of financing plant B with Defense Plant Corporation, a thorough check has been made of the need and the security, and DPC has agreed to loan the plant the money needed.

Meanwhile PAW'S labor counselor has gone to work to get those six needed skilled workmen. He and the manpower committee in Houston may try to borrow men from other refineries. They may confer with everybody from the War Manpower Commission in Washington and its Regional Director in Dallas clear down to half a dozen local draft boards. They may get an improved labor priority, arrange for stationing recruiters in favorable employment offices, or even get the War Labor Board to grant a wage adjustment. By one means or another they get the required men

Eventually the materials arrive and the men go to work The district refining and manpower committees and the district directors keep in constant touch with the work, check the technique of the installation, try to keep the men on the job and working at what should be wartime speed, and hasten progress in every way they can. When operations start, they check and advise until the new unit is in production.

By the day appointed, the Army begins to receive its increase of the special lubricant. A job has been done, and if you think that it took some doing, you should follow some of the tough ones!

Note the part borne throughout by the industry committees. Only in obtaining the allocation of materials and money was PAW forced to travel alone. In everything else, from the first to the final operation, PAW and industry committees worked side by side to get the job done.

MONETARY VALUE OF COOPERATION

The services of the men who serve on the industry bodies and the men who serve under them in industry capacities are beyond price. Think what an army of government men would be required to do the same job. The oil fields and refining centers and shipping terminals would be crawling with them. If they were to be competent they would have to be taken from the industry—there would be no other source—which would leave the industry helpless.

Their value can not be measured in money, but what they save the government in dollars and cents alone should bring prayers of thanksgiving from the taxpayers.

BATTLES OF THE COUNCIL CHAMBER

Has the cooperation between the government and the industry always been conducted in a roseate glow of sweetness and light? Not by a couple of thousand

light years. Successful oil men are forceful individuals, with strong wills and strong opinions. Some are even gifted with strong language. They do not leave these assets at home when they accept service with PAW or on an industry committee.

Not all the pitched battles of the war have been in Europe or Africa or the Pacific area; some have been fought in Petroleum Industry War Council meetings with PAW. Some pretty stiff engagements have taken place in district offices.

These disputes are the exception, not the rule, but they are not to be taken lightly. Some of them have the bite and venom so often characteristic of a family row, and like any other family row they could lead to estrangement and even to divorce. That they have not done so is due to the centripetal force of a common objective: The winning of the war. Oil men, inside the government and out, are bent on victory, and their disputes are always about "how," not "whether."

THE PRESERVATION OF THE INDUSTRY

Joint concentration on the main objective is furthered by a common secondary objective, namely, the preservation of the industry. Mr. Ickes and Mr. Davies announced at the outset their determination to keep the industry intact, with its external and internal competitive vigor unimpaired, and to leave it intact and unimpaired when the war is over.

When the leaders of the industry sit in Council with executives of PAW they know they are dealing with men who have the ultimate interests of the industry at heart, men who for the most part came from the industry and expect to return to it and want a healthy industry to return to, but who are determined, nevertheless, that no consideration for the industry or for anyone in it shall interfere with winning the war. On this the industry men are equally determined, first because they are patriotic Americans, and second because, if the war is not won, there will be no free and competitive oil industry Under such circumstances agreement far outruns disagreement, and performance outruns both.

CASUALTIES OF WAR

The record of maintaining the industry intact has not been perfect. Some producers and refiners and many bulk and filling station operators have been caught by the economic dislocations of the war and been forced to fold up A few individualists have been unable or unwilling to accommodate themselves to the unavoidable paper-work of a government-guided cooperative effort and have quit in disgust. These casualties must be charged to Hitler and Hirohito, however, and not to Uncle Sam.

Against them may be set those who, but for the efforts of PAW, would have failed through lack of materials or crude or manpower, and those, particularly small refiners, who through government financing, or through diversion of crude to their plants, are stronger now than when the defense program started. If there had been no PAW, the industry's casualty list would almost certainly have been much longer than it is. And when the war is over the United States will still have a strong and hotly competitive oil industry, made up of majors and independents, little companies and big, in about the same balance as before.

THE THIRD PARTNER

In addition to the government and the industry, there is a third partner in this adventure, the man who owns a car or an oil furnace. His part is to use as little as possible.

How many of us save gasoline by never driving more than 35 miles an hour? How many of us, if we have saved a little gasoline, spend it on a Sunday excursion or a trip to a football game? How many of us make it a point to know a truck driver or station operator who will slip us an extra ten gallons? How many of us

lie to the ration board to get a higher ration rating than we need? How many of us unblushingly buy on the black market? How many of us, in short, make a practice of chiseling on our boys overseas and essential users at home?

Don't misunderstand me when I mention the boys overseas. The five gallons you use for a fishing trip will not come out of their allotment. They'll get what they need if every civilian in the United States has to walk or stay home. But that five gallons may be needed to take some war worker to and from his job, some overworked doctor on his round of calls, some Red Cross worker on an errand of mercy, some public utility service man to stop a house from being flooded with gas or a basement with water. Whatever your wishful-thinking friends may tell you at the club or on the street corner, there is not enough gasoline to go around, and what you use unnecessarily someone else must do without. The public is a necessary participant in this unusual and effective partnership.

A UNIQUE ADVENTURE

There you have it: A unique adventure in statecraft on an unprecedented scale.

Dozens of government agencies, now and in the past, have had their industry advisory committees. Advisory bodies, prompting from the wings but taking no part in the performance, have been a dime a dozen. At the other extreme, totalitarian countries have taken over whole industries or coerced them into doing the will of the State. Even some democratic countries have unified the war effort of an industry by assuming its direction and eliminating its internal competition.

But never before, so far as I know, have a great government and a great industry joined in close, coherent, and yet independent team-work, with the industry directing its own effort, with government aiding, guiding, and directing only where imperative, with every precaution to maintain competitive structure and competitive spirit unimpaired, with freedom of enterprise conserved and utilized instead of suppressed.

Here is something that students of political science may well study, against the day of another emergency which we hope may never come.

A PATTERN FOR PEACE?

Whether there is anywhere within it anything of a pattern for peace I also leave with you to study. Such tentative thoughts as I may express are purely my own, and are strictly unofficial.

My own belief is that when the emergency is over such authority as PAW has, of which it has had to exercise very little, should vanish into the pages of history and PAW with it. In my opinion any form of government control, beyond what policing may be necessary, will lead eventually to that worst of all forms of monopoly, a monopoly controlled by government.

I am opposed with equal vigor to economic planning dominated by government. I fail to see how it can succeed without killing competition, which has brought us, to stick to oil as an example, more gasoline of better quality at half the price in twenty years.

I fail to see, moreover, how it can succeed without going the whole road toward a government-controlled economy, which is to say statism as exemplified in Germany, and every step toward statism is a step away from democracy and freedom.

I wonder, though, whether this adventure in statecraft has not given us a glimpse of another possibility, the possibility of a measure of economic planning by joint industry-government consultation. PAW's experience has taught us that leaders of an industry and government representatives who know their problems can consult together for the common good, and that in such consultations

the industry men, jealous as they may be for their competitive positions, are as responsive as the government men to the needs of the common welfare. Is it impossible that they would be equally far-sighted and public-spirited in time of peace?

Leaders of industry have often suggested that if the anti-trust laws would permit them to get together they could curtail the evils of competition and yet retain its benefits. Perhaps they could, but I doubt that the public is willing to risk that the end would be price fixing and monopoly. It's a risk that I should not care to advocate. But if the government itself were a participant, through men familiar with the industry and sympathetic with its problems, the dangers might be avoided and the benefits gained.

These are tentative thoughts, as I have said; idle speculations to be revived, perhaps, when the emergency is over.

THE JOB GOES ON

But the emergency is not over, and the job goes on. The war demands more fuel and lubricants now than ever before. The industry and the government are determined that the demand shall be met, fully and without stint. They are supremely confident that together they can do it, because they know what they have already done Only a miracle could have done it, the miracle of a government-industry plan that worked.

Yes, it has worked. In the five and one-third years since Germany marched into Poland:

Daily crude oil production has been increased by nearly 36 per cent.

Daily refinery throughput has been increased more than 41 per cent.

Output of 100-octane aviation fuel has been increased by more than 5,000 per cent.

Overland transportation to the East Coast, to replace tankers lost or diverted, has been increased by 5,400 per cent

The largest crude oil pipe line in the world, 24 inches in diameter and 1,340 miles long, has been completed.

The largest pipe line in the world for carrying refined products, 20 inches in diameter and 1,475 miles long, has been completed.

9,033 miles of other pipe line have been completed, of which 3,150 miles have been dug up and relocated; 3,317 miles have been reversed in carrying direction; and 436 miles of gas line have been converted to oil. Thus a total of 15,600 miles have been put to work to replace tankers sunk or diverted to military use.

101,500,000 barrels of oil have been saved by conversion of heating facilities to other fuel.

Civilian gasoline consumption has been decreased by 16½ per cent.

Every overseas military need has been met.

A minimum of hardship and inconvenience has been visited upon the civilian population.

The needs of the allied and neutral world have been cared for by an integrated global program.

Without fail, except for difficulties of Army transport, the right product in the right amount has been at the right place at the right time.

IT COULDN'T BE DONE

It couldn't be done, ladies and gentlemen, and it has been done. Something new in government-industry cooperation has taken place, and the impossible has been made possible. Oil, the most vital munition of them all, is fighting and winning on every front, and a unique adventure in statecraft is succeeding.

BOOK NOTICES

Aquatic Plants of the United States

Fourth in the series of American Natural History Handbooks from Cornell University is a volume on aquatic plants of the United States by Prof. W. C. Muenscher. Treatment is given those species of vascular plants "which normally start in water and must grow for at least a part of their life cycle in water, either completely submersed or emmersed."

The book includes an introduction, key to 50 families, brief family descriptions, generic and specific keys, with statements of habitat and range of each species References to other literature are appended to some discussions of families and genera.

The outstanding feature of the work is the assemblage of excellent illustrations by Miss Abbe and Mr. Nickau. Almost all of the approximately 450 species treated, are figured. Most of the drawings are habit sketches, but many show details of flowers, fruits, seeds, roots, seedlings, pollen grains and other specialized or diagnostic characters. Distributions within the U. S. are stated in the text, but also are indicated by maps by states. Some of the maps are misleading because of incomplete data. Maps showing occurrence of species in every state seem unnecessary.

The brief introduction includes a few random notes on distribution, reproduction, storage and treatment of seeds for planting, and weight of seeds. Nothing exhaustive is presented. The discussion of reproduction, for example, includes two sentences. Portions are redundant. The data in Table 1, p. 4, could have been stated in one sentence.

Difficulty will be met in using the keys, since characters absent at flowering time in many species are referred to. While the descriptions show no improvement over those already extant, especially with regard to terminology, the author's notes from wide field experience are of interest. The figures, however, appear to be the useful part of Professor Muenscher's work which is, in all, a worthwhile compilation of information concerning some of the aquatic plants of the United States.

Aquatic Plants of the United States. Walter Conrad Muenscher. Comstock Publishing Co., Inc. Cornell University. Ithaca, N. Y. 364 pp., 157 plates, 400 maps, glossary, index. Price $5.00. 1944.

Coat-Color Change in Weasels

In this study the authors tested the effects of the duration of light upon the seasonal coat-color changes of weasels. The length of the light period in the day and night cycle was controlled by the use of artificial illumination and shifting the caged animals into a dark room. Control animals were maintained in each experiment. Individuals of two different species of weasels were used for this study: ***Mustella frenata noveboracensis***, the New York Weasel, and ***M. cicognanii cicognanii***, Bonaparte's Weasel

Changes of coat color in both species was accomplished by shedding of old hair and the growing out of new hair of a lighter or darker shade. This coat-color change was found to follow a pattern upon the body. In general this was from the ventral towards the dorsal surface.

Periods of reduced light duration induced moulting and the regrowth of hair of a lighter shade. Increasing the duration of daylight also induced moulting and the regrowth of hair of a darker shade. By reversal of increase or decrease of the daily light duration, incomplete mounts were obtained in both directions. By proper manipulation of the direction of light duration changes, it was possible to leave an animal for some time with parts of its body covered with hairs from three consecutive growths of hair.

The data from this study indicates that temperature change was not a factor in pelt modification or color cycles in these two species of weasels. Following Bissonnette's work on ferrets and Lyman's study of the varying hare the authors express the opinion that the stimulus for coat-color modification is received through the eyes and probably acts through the anterior lobe of the pituitary gland; also that the thyroids and sex glands are not essential to elicit this response.

—*Wilbur M. Tidd.*

Experimental Modification and Control of Moults and Changes of Coat-Color in Weasels by Controlled Lighting, by Thomas Hume Bissonnette and Earl Elmore Bailey. Annals of The New York Academy of Sciences, Volume XLV, Art. 6. Pages 223–260, 7 pls., 1 graph. April 7, 1944. Published by The New York Academy of Sciences, Central Park West at Seventy-ninth Street. Price $0.75.

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EFFECTS OF GLIOTOXIN ON TRICHOPHYTON GYPSEUM[1]

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The need for better therapeutic agents for the control of tenia pedis (athlete's foot), a disease most frequently caused by *Trichophyton gypseum*, is appreciated by the layman as well as by the dermatologist. Within the past few years, great strides have been made in the use of antibiotics in the treatment of bacterial infections. The possibility that an agent of this kind may prove valuable in the therapy of fungous infections is deserving of serious consideration.

Weindling (6, 7, 8 and 9), in his discovery, isolation and subsequent study of gliotoxin, has done significant pioneer work on the action of antibiotics upon fungi. Much additional chemical and biological data concerning gliotoxin have been contributed by Bruce and his colleagues (1, 2, 3, 4 and 5). Not only was this one of the first antibiotic substances to be studied in great detail; it is the only one which has been extensively investigated as a fungicide. Because of the circumstances involved in the discovery of this substance, its effect on phytopathogenic rather than human pathogenic fungi has received the major emphasis.

With the above facts in mind, experiments were carried out to determine the effects of gliotoxin on the dermatophyte, *T gypseum*. Small amounts of gliotoxin were obtained on several occasions by culturing *Gliocladium fimbriatum* on a liquid medium. Except as noted, the methods used in the culture of the *Gliocladium* and in the extraction of the toxic agent were as described by Weindling (7). About 200 ml. of medium were placed in each of six 32-oz. prescription bottles. After the medium had been sterilized and inoculated, the cultures were incubated on a shaking machine operating at a rate of about 100 oscillations per minute. After three days of incubation, the gliotoxin was extracted.

The ability of gliotoxin to inhibit the growth of *T. gypseum* was next determined. Suitable amounts of gliotoxin were added to sterile culture media. Both Sabouraud's agar plates and flasks containing Chapek-Dox broth were inoculated with spores and incubated at room temperature. A concentration of 0.001% gliotoxin in the above media was found to prevent completely the growth of the test organism. The next concentration in the series, i. e., 0.0001%, had no visible inhibitory effect.

To determine the fungicidal powers of this substance, washed spores of *T. gypseum* were suspended in gliotoxin solutions in which the gliotoxin had been dissolved in 0.1 M KH_2PO_4. At hourly intervals, 5-ml. samples of the spore suspensions were centrifuged and the supernatant fluid removed. The spores were then washed in sterile water, and a loopful of the concentrated spores transferred

[1]The writer wishes to express his appreciation to Dr. Richard Weindling for a culture of *Gliocladium fimbriatum*, to Dr. C. W. Emmons for a culture of *Trichophyton gypseum* (U. S. Public Health Service culture No. 601, *T. mentagrophytes*), and to Dr. W. F. Bruce for a sample of crystalline gliotoxin of known purity, all of which were essential to the execution of this project.

to an agar slant to test their viability. A concentration of 0.01% of gliotoxin was found to kill from 99 to 100% of the spores in two hours. No actual spore counts were made, but there was no growth except in an occasional tube where a few isolated mycelia developed. The next dilution tested, i. e., 0.001%, was not fungicidal even after 24 hours.

The above experiments were repeated using gliotoxin of known purity. The results were essentially the same as those obtained with the material prepared in this laboratory.

The ultimate question of therapeutic value of gliotoxin in the treatment of human infections can be answered, of course, only by clinical tests.

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Quantum Chemistry

Quantum Chemistry, by Eyring, Walter, and Kimball is a recent book dealing with quantum mechanics. The title seems a little anomalous since the contents are essentially those contained in any other book dealing with quantum theory, but perhaps physics when treated by the chemist becomes transmuted into chemistry. The book devotes three chapters to the transition from classical quantum theory to modern quantum theory. Following the fourth chapter discussing several of the most important differential equations in which the Schrodinger equation manifests itself, there are two chapters devoted to perturbation theory and radiation theory. After a discussion of the application of quantum theory to atomic structure the authors preface, what may be regarded as the section on molecular phenomena by a chapter on group theory. At the end are nine appendices emphasizing several useful topics of a more specialized nature

The principal criticism which this reviewer can offer on this book is that the material is extremely condensed and very few of the topics are treated with thoroughness. A student wishing to become initiated into quantum mechanics could almost certainly choose another book which would be more helpful than Quantum Chemistry.—*H. H. Nielsen.*

Quantum Chemistry, by H. Eyring, J. Walter, and G. Kimball. vi+394 pp. John Wiley and Sons, Inc. 1944.

Bibliography of Biographies of Entomologists

This paper brings up-to-date the first complete work on the subject published by Mr. J. S. Wade in the Annals of the Entomological Society of America, 21: 489-520, 1928. It is intended to be complete through the year 1943 and has been broadened in scope so that it includes biographical data for entomologists of all countries. The references include obituaries, birthdays, portraits, anniversaries, biographies and disposition of collections.

Compilations of this type are very worthwhile and the author is to be commended for a spare-time job well done.—*R. H. Davidson.*

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THE MICRO DETERMINATION OF TISSUE LIPIDS

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Recent interest in the nature and content of the lipids of tissues is constantly demanding more accurate methods for their determination The present work was initiated as a result of the need for improved methods of estimating certain of the lipid fractions of glandular lipids in collaborative studies now under way between the departments of Physiological Chemistry and Anatomy (1).

A literature survey of extraction methods led us to the conclusion that complete lipid extraction can be attained by various methods and solvents. Obermer and Milton (2) and Rose and Riegel (3) reported that the 3 : 1 alcohol-ether solvent of Bloor and 1 : 1 alcohol-acetone of Schoenheimer and Sperry (4) are equally effective. Sperry (5) showed that extraction with these solvents is complete at room temperature for glandular tissues. We have confirmed these findings for beef liver and guinea-pig adrenal tissue, the former being relatively low and the latter high in lipid content.

A saponification method was developed from that of Bloor, using potassium hydroxide in alcohol-ether as described by Kelsey (6) Our method gave complete saponification of pure methyl esters of fatty acids, mixed triglycerides and pure cholesterol esters. Previous micro methods for the determination of fatty acids have generally been non-specific in nature, as, for example, the methods employing nephelometry, chylomicron count and dichromate oxidation. The titrimetric method of Stoddard and Drury (7) is specific as it measures the total carboxyl content after saponification and isolation of the fatty acids It is a direct measure of the fatty acids provided their neutralization equivalent (mean molecular weight) is known. A simplified modification of the titrimetric method was developed and was tested against pure fatty acids.

The determination of cholesterol (both free and combined) was critically studied. Of the numerous methods proposed by other investigators, those based on the Liebermann-Burchard color reaction or the Windaus digitonin precipitation are the most widely accepted at present. The combination of the two principles by Kelsey (6) and by Schoenheimer and Sperry (4) has improved the accuracy and specificity of the analysis. These two methods were subjected to careful study. The Kelsey method in our hands gave erratic results even after considerable experience had been acquired in the use of the method. We could not use the Schoenheimer and Sperry procedure in its last detail because it required a specially designed colorimeter which was not available. A modification of their method was developed which can be used in an ordinary colorimeter and in the Evelyn Photoelectrometer, which we have employed. The method was found to give accurate results on both ester and free cholesterol.

In our experience we have found the phospholipid method of Bloor (8) to give satisfactory results in the determination of this lipid fraction.

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[2]Aided by grants from the Comly Research Fund of the College of Medicine.

EXPERIMENTAL

I. Extraction of Tissues

Beef liver tissue was used in one series of studies of extraction methods. The tissue was ground up thoroughly and mixed well before the samples were weighed. Fifty ml. of 3 : 1 alcohol-ether was added to each sample and the extraction accomplished as indicated in Table I. The extracts were filtered into Erlenmeyer flasks and the extraction flasks washed with two 25 ml. portions of the solvent. The total extract was evaporated almost to dryness under reduced pressure and the residue extracted with petroleum ether. Total fatty acid and total cholesterol were determined on the petroleum ether extract by the method described later, the results appearing in Table I.

TABLE I

Analyses of Lipid Extracts of Beef Liver

Method		Weight of Sample mg.	Fatty Acid %	Fatty Acid Avg.	Cholesterol %	Cholesterol Avg.
Grind with sand, stand twelve hours with solvent	1	753.8	3.72	....	0.278	....
	2	552.8	3.50	3.61	0.244	0.261
Grind with sand, stand twelve hours at room temperature with solvent	1	661.2	3.77	....	0.270	.....
	2	567.0	3.40	3.58	0.240	0.255
Grind with sand, boil five minutes with solvent, stand twelve hours	1	721.0	3.56	....	0.277	.....
	2	616.6	3.46	3.51	0.252	0.264
Grind with sand, reflux one hour, stand twelve hours	1	584.8	3.39	.....	0.261	.....
	2	549.4	3.39	3.39	0.238	0.250
Saponify tissue ninety minutes, ext. with solvent after acidification.	1	346.2	3.41	...	0.240	.....
	2	166.1	3.73	3.55	0.277	0.258

The average results in Table I indicate that essentially complete extractions were attained on liver tissue by the five procedures as described. Results by the saponification method serve as a standard of comparison.

Two of the procedures, described in Table I, were applied to a specimen of adrenal tissue of an old guinea pig. The two adrenals of this animal weighed 619 mg. The tissue was ground and mixed and four samples treated as described in Table II. This time, however, free and total cholesterol, phospholipid and total fatty acid were determined, the results serving to compare the efficiency of extraction by the two procedures.

Since the previous data showed complete extraction by standing for twelve hours at room temperature, this procedure was adopted. The details we have adopted for preparing a lipid extract follow.

Extraction Procedure

The fresh tissue sample was weighed by difference from a ground-glass stoppered weighing bottle into a mortar, mixed with sand, and ground up as described by Bloor (8). The mixture was transferred quantitatively to a 125 ml. Erlenmeyer flask. The mortar and pestle were washed with 1 ml. distilled water, and then with portions of the solvent. A total of 40 ml. 3 : 1 alcohol-ether (redistilled solvents) was added to the tissue. The flask was stoppered and allowed to stand

at room temperature overnight. The extract was then filtered through a fat-free filter paper into a 125 ml. Erlenmeyer flask. The residue on the filter was washed with two 15 ml. portions of fresh solvent and the washings added to the main extract. The combined extracts were evaporated almost to dryness under reduced pressure. A trap of the type used in the Van Slyke determination of nitrogen was convenient for this process. The flask was heated in a water bath placed on the steam bath. When a small aqueous residue remained in the flask, the trap and flask were disengaged from the suction tubing. From 7 to 9 ml. petroleum ether in three small portions was washed through the trap into the flask. The flask was then removed from the trap and stoppered. When a series of samples had reached this point, they were all extracted three times with petroleum ether. The petroleum ether was decanted into 15 ml. centrifuge tubes. The solvent was evaporated off before the second and third extractions of the residue were added to the tube. The substance thus extracted into the centrifuge tubes represented the total lipid and was used for the differential anlaysis of the lipid fractions.

TABLE II

LIPID ANALYSES OF GUINEA-PIG ADRENAL, FOLLOWING TWO EXTRACTION METHODS

Method	Weight of Sample mg.	Phospholipid		Free Cholesterol		Total Cholesterol		Fatty Acid	
		%	Avg.	%	Avg.	%	Avg.	%	Avg.
Grind with sand, reflux one hour, stand twelve hours, room temperature....	116 7	3 07		0 21		1.18	.	14 58	. . .
	78 9	2 73	2 90	0.25	0 23	1 26	1 22	16.30	15 54
Grind with sand, stand twelve hours, room temperature	88 3	2 95	. . .	0.27	. .	1 27		15.50	. .
	100 0	3 19	3 07	0.23	0 25	1 27	1.27	16 18	15 84

II. THE SAPONIFICATION PROCEDURE

The efficiency of saponification by the Bloor method as described by Kelsey (6) was first tested on a specimen of pure cholesteryl palmitate, especially prepared for the purpose. The palmitic acid recovered from the saponification was estimated by the titration method, described in the next section of this paper. The results were erratic, the recovery of palmitic acid varying from 77 to 93 per cent on five samples. The method of saponification was therefore modified (see description below) and tested on a specimen of pure cholesteryl oleate. Preliminary tests on employing the method with a reaction time of 30, 60, and 90 minutes showed that even with this cholesteryl ester a thirty minute saponification is complete, recovery of the oleic acid being over 99 per cent.

Description of Procedure

The lipid to be saponified was dissolved in 5 ml. of 3 : 1 alcohol ether in a 15 ml. centrifuge tube, and 0.2 ml. of 30 per cent aqueous KOH added. If complete solution did not occur after vigorous stirring, alcohol up to 2 ml. was added. The tube was warmed in a beaker of hot water on a steam bath, the solution being allowed to boil gently for 30 minutes. Bumping was prevented by a boiling rod. The beaker was then placed on a hot plate and the solvent boiled off rapidly and completely. The tube was removed from the beaker and allowed to cool. To the aqueous residue was added just enough 1.8 N HCl to make the mixture slightly acid. The mixture was stirred vigorously and then 7 ml. petroleum ether added

and the mixture again stirred. The tube was allowed to stand about fifteen minutes, and then the petroleum ether solution was decanted from the water layer with the suction apparatus described by Bloor (8). The fatty acid solution was decanted into the 25 ml. Erlenmeyer flasks in which the titration was to be performed. The aqueous residue was re-extracted with two portions of petroleum ether and the extracts combined. The ether was evaporated off and the residue dissolved in alcohol and titrated.

In addition to the cholesteryl palmitate and oleate, previously mentioned, the procedure was tested on a specimen of mixed glycerides of olive oil (mean molecular weight of fatty acids 282), a specimen of brain lecithins, and a known synthetic mixture of all four types of lipids. The results are given in Table III.

TABLE III

EFFICIENCY OF FATTY ACID RECOVERY BY MODIFIED SAPONIFICATION PROCEDURE

Fatty Acid in Sample mg.	Number of Determinations	Sample	Fatty Acid Recovered mg.	Recovery Avg. Per Cent
5.39	3	Methyl palmitate...	5 32	98 0
6.18	3	Mixed triglycerides....	6 16	100.2
8.40	3	Lecithins..........	8.31	99 0*
4 02	3	Cholesterol oleate..	4 00	99 4
10.00	4	Mixed esters (above four)..	10 05	100 4†

*Range of recoveries 98.2–100.4%.
†Range 100.1–101.2%.

III. A Titrimetric Method for the Determination of Fatty Acids

The fatty acids employed in this work were highly purified specimens, prepared especially for solubility determinations by H. F. Foreman (9) in this laboratory.

In preliminary work the oxidative method of Bloor (10), applied to oleic acid, was found to give satisfactory results, recoveries on 5 mg. samples being 96 to 102 per cent. The titration method of Stoddard and Drury (7) also proved satisfactory. It was our experience, however, that phenolphthalein possessed some advantages over thymolphthalein. This latter indicator goes through a series of color changes from colorless to yellow to green to blue in alcoholic solution, thus making the end-point difficult to determine. Our titrations with 0.035 N alkali were carried out with a special burette. The details of the method and results follow.

Description of Titrimetric Method

An automatic 5 ml. Exax burette, graduated to hundredths, was fitted with a special tip which delivers 150 drops per ml. solution. The standard alkali was kept in a paraffin coated bottle protected from the carbon dioxide of the air by Ascarite and concentrated alkali traps. The sample of fatty acid, usually in petroleum ether solution, was measured into a 25 ml. Erlenmeyer flask and the solvent evaporated off. The residue was dissolved in 10 ml. 95 per cent alcohol, measured by a pipette. From 5 to 7 drops of 1 per cent phenolphthalein was added, and the sample titrated to the first faint pink color. A series of blank titrations on 10 ml. samples of the alcohol was made and the titrations corrected accordingly. The blank amounted to 0.063 ml. The alkali used in the titration was standardized against Bureau of Standards potassium acid phthalate. Results on pure oleic, palmitic and stearic acids are shown in Table IV.

TABLE IV

THE TITRIMETRIC DETERMINATION OF PURE FATTY ACIDS

Specimen	No. of Det'ns	Alkali ml. (Corrected)	Fatty Acid		Recovery Per Cent
			Taken mg.	Found mg.	
Alcohol Blank.	5	0 063	.....	.....	...
Stearic Acid	5	1 173	11 30	11 31	100
" "	3	0.581	5 65	5 60	99
" "	2	0 459	4 52	4 43	98
" "	3	0.351	3 39	3 35	99
" "	2	0.236	2 26	2.27	100
" "	3	0.118	1.13	1 14	101
Palmitic "	2	1.240	10.76	10.76	100
" "	3	0 613	5.38	5 31	99
" "	3	0.381	3.23	3.30	102
Oleic "	1	1 171	11 30	11 19	99
" "	2	0.353	3 39	3 38	100

IV. AN INVESTIGATION OF FREE AND COMBINED CHOLESTEROL PROCEDURES

Pure samples of cholesterol were prepared from beef brain tissue. Standard stock solutions of this cholesterol were made up in petroleum ether and kept tightly stoppered at 0° C. Samples were measured from these stock solutions for all subsequent analyses on pure cholesterol.

The Evelyn photoelectrometer (11) was used throughout the investigation for the measurement of the color intensity of the cholesterol samples. The galvanometer reading, G, when calculated to L, or (2-log G), should give a straight line of slope K when plotted against the weight in mg. of cholesterol in the samples.

The accuracy of the color determination as recommended by Kelsey was first studied. The samples were measured from the stock solutions into 25 x 200 mm. soft glass test tubes which had been optically tested for use in the photoelectrometer. The solvent was evaporated off, and 10 ml. chloroform, 1.0 ml. acetic anhydride, and 0.1 ml. concentrated sulfuric acid were added to each tube. The samples were well stoppered, mixed, kept at a temperature of 23° C. for twenty minutes and read in the instrument. The average values for K found for two series of twenty samples from 0.1 to 1.0 mg. in size, were 0.68 ± 0.054 and 0.71 ± 0.061. The variation is over 8 per cent.

Kelsey's method of separating free and ester cholesterol by digitonin precipitation was next studied. It involves the evaporation to dryness of a mixture of the lipid and a solution of alcoholic digitonin. Extraction of the residue with petroleum ether removes the cholesterol ester and other lipids. The cholesterol digitonide is decomposed by refluxing it in benzene. The addition of petroleum ether to the hot benzene dissolves the cholesterol and the digitonin is precipitated. The variable results by this method are shown in Table V.

A further study of the method was made on samples of pure cholesterol, in which the amount of cholesterol not precipitated by the digitonin, the amount not decomposed by the benzene, and the amount normally determined by the Kelsey method were determined. These three fractions were determined by our modified method described below. The comparatively large samples were used in order to establish the limits of the method when 5 ml. 0.2 per cent digitonin solution was used. The results are shown in Table VI.

In the Schoenheimer and Sperry method (4) the cholesterol is quantitatively precipitated as the digitonide in a mixture of equal parts of absolute alcohol,

acetone, and water. The washed and dried precipitate is then dissolved in 1 ml. of hot glacial acetic acid and the solution is cooled. Two ml. of acetic anhydride and 0.1 ml. of concentrated sulfuric acid are added and the color intensity of the solution determined after twenty-five minutes at 25° C. In order to use the

TABLE V

THE DETERMINATION OF FREE AND ESTER CHOLESTEROL IN KNOWN SYNTHETIC MIXTURES BY THE KELSEY METHOD

Composition of Sample	Recovery of Free Cholesterol		Recovery of Ester Cholesterol	
	mg.	Per Cent	mg.	Per Cent
0.491 mg. free, 0.491 mg. ester	0.478	97	0 540	110
0.491 mg. free, 0 0 mg. ester	0.468	96	0 064	.
0.0 mg. free, 0 491 mg. ester	0 087	..	0 469	96
0.261 mg. free, 0 0 mg. ester	0 228	88	..	...
0 261 mg. free, 0.491 mg. ester	0 235	90		.
0 261 mg. free, 0 786 mg. ester	0.269	103	..	.
0 261 mg. free, 0 982 mg. ester	0 284	109	..	.
0 417 mg. free, 0.0 mg. ester	0 383	92		.
0 823 mg. free, 0 0 mg. ester	0.711	86	.	.
0.0 mg. free, 0 491 mg. ester	0 019	...		
0.0 mg. free, 0.786 mg. ester	0 019			

TABLE VI

CHOLESTEROL DETERMINATION BY KELSEY METHOD

Cholesterol in Sample	Cholesterol Not Precipitated		Cholesterol In Residue		Cholesterol Determined	
mg.	mg.	Per Cent	mg.	Per Cent	mg.	Per Cent
0 166	0 005	3 0	0.005	3.0	0.141	84.8
0 333	0 027	8 2	0.012	3 0	0 288	86.4
0 498	0 065	13 2	0.012	2.5	0.414	83.0
0 834	0.000	0.0	0.034	4.1	0.789	94.6
1 668	0.108	6.5	0.311	18.6	1.227	73.5
2 502	0 006	0 2	0 852	34 0	1 643	65.7
3 336	0.539	16.2	1.051	31.4	1.762	52 8
4.270	1 386	32.5	1 106	25.9	1 864	43 7
5 002	2.080	41.6	0.754	15.1	2.160	43.2

Evelyn photoelectrometer in our work, all the reagents were doubled and the color intensity read through the 6 ml. aperture. On samples of cholesterol from 0.1 to 0.4 mg., the value of K was found to be 1.04±0.04. Corrected to a volume of 11 ml. for comparison with the value of 0.70±.06 obtained by the Kelsey method, K becomes 0.57±0.02. This lower value for K explains why small samples of cholesterol are more difficultly determined using acetic acid as the solvent.

Investigation revealed that the cholesterol digitonide could be dissolved in a relatively small volume of hot glacial acetic acid. To this solution, chloroform could be added without causing the precipitation of either the cholesterol digitonide or free digitonin. The color intensity of this solution approached that of a chloroform solution of cholesterol and could easily be read in the photoelectrometer even in 12 ml. volumes.

Experiments were conducted to ascertain the most effective concentration of each reagent, glacial acetic acid, chloroform, acetic anhydride, and sulfuric acid, as well as the most desirable temperature for the color reaction. The results are shown in Table VII.

TABLE VII

THE LIEBERMANN-BURCHARD COLOR REACTION: EFFECT OF TEMPERATURE AND CONCENTRATION OF REAGENTS

Sample	No. of Samples	Light Filter	ml.				Temp.	K	Time
			Acetic Acid	Chloroform	Anhydride	Sulfuric Acid			
Cholesterol	40	6600	0	10	1	0.1	23	0.70	20
Cholesterol	5	6600	0	10	1	0.1	25	0.73	25
Cholesterol	5	6600	0	10	1	0.1	17	0.59	65
Cholesterol	5	6200	4	0	8	0.4	26	0.65	30
Cholesterol	5	6200	4	0	8	0.4	27	0.65	35
Cholesterol	5	6200	4	0	8	0.4	18	0.57	65
Cholesterol	5	6200	2	8	2	0.5	32	0.83	12
Cholesterol	6	6200	2	8	2	0.5	16	0.81	50
Digitonide	5	6200	4	0	8	0.4	18	0.52	75
Digitonide	1	6200	2	0	10	0.5	18	0.66	
Digitonide	1	6200	6	0	6	0.5	18	0.53	.
Digitonide	1	6200	2	3	7	0.5	18	0.70	.
Digitonide	1	6200	2	4	6	0.5	18	0.68	
Digitonide	1	6200	2	5	5	0.5	18	0.74	
Digitonide	1	6200	2	6	4	0.5	18	0.75	
Digitonide	1	6200	2	8	2	0.5	18	0.73	
Digitonide	1	6200	2	9	1	0.5	18	0.66	.
Digitonide	1	6200	2	8	2	0.2	18	0.45	110
Digitonide	1	6200	2	8	2	0.4	18	0.73	65
Digitonide	2	6200	2	8	2	0.5	18	0.72	60
Digitonide	1	6200	2	8	2	0.7	18	0.70	45

The precipitation of the cholesterol as the digitonide by the Schoenheimer and Sperry method was incomplete for samples of 0.1 to 0.5 mg. This is indicated in Table III, where the digitonide gives consistently lower values for K than the pure cholesterol samples after comparable treatment. Increasing the volume of 0.2 per cent aqueous digitonin solution from one to four ml. per sample did not result in the quantitative precipitation of the cholesterol. However, by using 2 ml. of 0.4 per cent aqueous digitonin, 2 ml. acetone, and 2 ml. alcohol and carrying out the precipitation at a lower temperature, quantitative results were obtained as shown in Table VIII.

TABLE VIII

THE PRECIPITATION OF CHOLESTEROL DIGITONIDE

Volume of Digitonin Solution ml.	Temperature °C.	L	Cholesterol Calculated mg.	Cholesterol Recovery Per Cent
6	26	0.260	0.321	98
6	26	0.254	0.314	96
6	16	0.260	0.321	98
6	8	0.260	0.321	98

Description of Cholesterol Procedure

To the lipid sample in a 15 ml. centrifuge tube was added 2 ml. each of acetone, alcohol and 0.4 per cent digitonin solution (prepared by evaporating a solution of one gram digitonin in one liter distilled water to 250 ml.). The mixture was stirred thoroughly and the tube was stoppered and placed in the refrigerator overnight. The tube was then centrifuged at a high rate of speed for ten minutes and the supernatant liquid decanted. The precipitate was washed with acetone-ether and then with ether as described by Schoenheimer and Sperry. The precipitate was dried by placing the tube in a beaker of warm water. The tube was then placed in a pan containing about two inches of sand and kept in an oven at about 120° for about twenty minutes. Then the pan and its contents were removed. Two ml. of glacial acetic was pipetted into the tube and the contents of the tube well mixed. The tube was removed from the sand bath after a few minutes and allowed to come to room temperature. Ten ml. of the color reagent was pipetted into the sample. The reagent was prepared by mixing 20 ml. acetic anhydride (C. P. 99 per cent), 80 ml. chloroform, C. P., and 5 ml. concentrated sulfuric acid. The chloroform and anhydride may be measured in a graduated cylinder and the sulfuric acid measured in an ordinary pipette. The reagent is kept at 16° C. and is usually prepared fresh for each set of ten samples. After the addition of the reagent to the sample, the solution was mixed thoroughly and transferred to the colorimeter tubes. The transfer is not necessarily quantitative, since the color intensity of the sample is to be measured. The colorimeter tube was stoppered immediately and placed in a beaker containing water at 16° C., and covered with a heavy towel. The beaker was placed in the constant temperature refrigerator at 16° C. The color intensity of the solution was read in the Evelyn photoelectrometer after about fifty minutes standing, using the 6200 Å light filter. The readings were checked at intervals of five minutes until a constant maximum reading was obtained. The blank reading was checked at 100 between each sample reading.

The standardization curve obtained by the above method on both pure cholesterol and cholesterol digitonide gave a value for K of 0.81 ± 0.01 for the former, and 0.82 ± 0.01 for the latter. The variation is ± 1.5 per cent.

SUMMARY

Procedures are described for the extraction of tissue lipids and for the saponification of these lipids. The lipids of liver and adrenal tissues are completely extracted by 3 : 1 alcohol-ether in five hours at room temperature. Glycerides, cholesterol esters and methyl esters were shown to be completely saponified by heating for thirty minutes with a solution of potassium hydroxide in alcohol-ether. An improved titrimetric method for the estimation of fatty acids is described. Amounts of fatty acids from 1–10 mg. can be determined with an accuracy of ± 2.0 per cent. A modification of the Schoenheimer and Sperry method for determination of free and combined cholesterol has been devised, after critical study of the best conditions for precipitation of cholesterol digitonide and the development of color in the Liebermann-Burchard reaction. The modified method is adapted for use in the Evelyn Photoelectrometer, and may be used in other colorimeters of this type.

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STUDIES ON FRESH-WATER BRYOZOA

XV. Hyalinella punctata Growth Data

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INTRODUCTION

The fresh-water Bryozoa constitute a small group of widely distributed species. They may reproduce by some of the following methods: (1) budding, (2) chitin encased germinable bodies called statoblasts and hibernacula and (3) free-swimming larvae. Statoblasts occur in most fresh-water Bryozoa while hibernacula occur in only a limited number of species. These well-encased bodies often tide the species over periods of adversity, drought or winter cold. Tampering with the life cycle can be done most easily by experimenting with the statoblasts and hibernacula, since these bodies are hardy, can be chilled, dried or otherwise handled with relatively little care.

The purpose of the present article is to furnish data on the viability of floating statoblasts, known as floatoblasts (Rogick, Study XIV), the rate of formation and degeneration of individuals and the development and growth processes of floatoblast-derived colonies of *Hyalinella punctata*. The data herein given consist of observations on specimens whose life cycle had been experimentally delayed or tampered with in some way.

Difficulties of various types are encountered in studying living bryozoa. One is the matter of identification, which is particularly troublesome in the Plumatellidae of which *Hyalinella* is a member. Another difficulty is the feeding problem. A third is the maintenance of the colonies in the laboratory under such conditions as make it easy to study them conveniently under the microscope without disturbing them too much. This requires that they be grown in shallow dishes like Syracuse watch glasses or Petri dishes which can be placed readily under the compound microscope for examination. Colonies or coenoecia may or may not become attached to the substratum under laboratory conditions. Some attach within two or three days after germination of the floatoblasts which produced them, while others remain suspended from the surface film for a number of days. Eventually however, all will attach. Those which attach to the bottom of the dish are in a very favorable position for microscopic study. Those which attach to the sides or rim of the dish or to the surface film generally orient downward, necessitating their dislodgment with a dissecting needle so that they will lodge in a more favorable situation.

DESCRIPTION OF FLOATOBLAST GROUPS

Study VIII (Rogick, 1939) reported a part of the *Hyalinella punctata* life cycle which dealt with the metamorphosis of the free-swimming larvae into young colonies. No larvae were produced by the colonies of the present study which deals with colonies derived from the following seven groups of *Hyalinella punctata* floatoblasts:

GROUP P. This group consisted of 42 floatoblasts dried a few days after collection and stored dry at room temperature for many months until the start of the experiment. None germinated.

GROUP Q. This consisted of 20 floatoblasts not dried until a number of months after collection, then stored dry, at room temperature, for a number of months until the start of the experiment. Half of them gave indications of germinating but did not complete the germination process to the point where visible polypides were protruded.

GROUP R. This consisted of floatoblasts chilled, then dried soon after collection and stored under these conditions in a refrigerator for a number of months until the start of the experiment. Of the 135 floatoblasts set out 96 germinated.

GROUP S. This consisted of floatoblasts remaining in water at room temperature for a number of months, then stored wet, i. e., in water in a refrigerator for several months until the start of the experiment. Of the 42 set out 12 germinated.

GROUP T. This consisted of 25 floatoblasts which remained in water at room temperature for a number of months until the start of the experiment. Five or one-fifth germinated.

GROUP U. This consisted of floatoblasts remaining in water for many months at room temperature after which they were dried and stored dry in a refrigerator until the start of the experiment. One out of 45 germinated.

GROUP V. This consisted of 14 floatoblasts which were dried sooner after collection than were those of Group R and which were stored dry in a refrigerator for a number of months before the start of the experiment. None germinated.

Briefly, Groups P, Q and T were not subjected to chilling and storage in the refrigerator at any time during the experiment. Groups R, S and V were. Group U was subjected to chilling and storage at low temperatures for only a part of its dormant period. Also, Groups P, R and V were stored in the dry state during their dormant period while Groups S and T remained wet throughout their entire period. Groups Q and U were subjected to drying only after the statoblasts had remained free in water for a number of months.

The official "start" of each experiment was the removal of floatoblasts from their places of storage and their immersion in tap water at room temperature for purposes of germination.

Three sets of floatoblasts, P-1, P-2 and P-3, were used in the P Group. Sets P-1 and P-3 were collected from Westtown Pond in Westtown, Chester County, Pennsylvania, on Sept. 9, 1940, dried four days thereafter and stored dry at room temperature in corked vials on a closet shelf until wanted for experimentation. Set P-2, collected from Beechmont Lake in New Rochelle, New York, on Aug. 8, 1937, was similarly treated but was dried eight days instead of four after collection. The method of desiccation was the same as described in Studies VII and XI. Sets P-1 and P-2 were "started" or immersed in tap water on June 29, 1941, and Set P-3 on Feb. 3, 1943, so that germinations might take place. Since none did and none seemed likely to, Sets P-1 and P-2 were discontinued 33 days after the start of the experiment and Set P-3 was discontinued 116 days after the start or immersion. Table I gives additional data on the conditions under which each set of this and other groups was kept.

Like floatoblasts of Sets P-1 and P-3 those of Groups Q, R, S, T, U and V were collected at Westtown Pond on Sept. 9, 1940.

At the time of collection a number of floatoblast-filled colonies of *Hyalinella punctata* were brought indoors from the pond. These colonies in due time normally released a large number of floatoblasts which were placed in a pint Mason jar with some *Elodea* and water. This jar was kept indoors at a comfortable room temperature from the time of collection until Aug. 2, 1941, or for a period of 327 days or 10.8 months, throughout the autumn, winter, spring and part of the summer. From this jar came the floatoblasts which were used in Groups Q, S, T and U.

Those which were to be used in the Q Group were removed from the jar on Aug. 2, 1941, dried, then stored dry in a corked vial on a closet shelf at room temperature for 18 months, until Feb. 3, 1943. They were then "started" or immersed in tap water and kept at a comfortable room temperature throughout their germination period. Half of the statoblasts did give some indication of germinating. They reached the point where the two floatoblast valves separated sufficiently to permit a glimpse of a small ball of tissue between them. This tissue however did not grow beyond the borders of the valves nor did it develop any visible or protrusible polypides. This group was discontinued 47 days after immersion because the ones which had begun to germinate were dead for some time and the others gave no indication of germination.

Floatoblasts for Group S were removed from the same pint jar containing *Elodea* and water as were those of Group Q, on Aug. 2, 1941. Thus they had remained in liquid at a comfortable room temperature for 327 days or 10.8 months. They were then placed in a refrigerator where they remained in liquid at the bottom of a small corked bottle from that date till Jan. 24, 1943, an interval of 540 days or 17.7 months. They were removed from the refrigerator on that date 28.5 months after collection, immersed in a watch glass containing tap water and kept thus at a comfortable room temperature from then on. The temperature and other data for this group can be found in Tables I and II. Twelve of the 42 floatoblasts used in this group germinated very speedily, eleven of them within one day after immersion and the twelfth on the second day after immersion. Most of the colonies derived from these germinated floatoblasts were discontinued between 16 and 32 days after floatoblast immersion because degeneration, due to improper (green algal) and insufficient food, had set in and the colonies were too degenerate to be saved. One colony was accidentally crushed 31 days after floatoblast immersion. The remaining floatoblasts were discarded 78 days after immersion because they had failed to germinate. Please refer to Table I for additional data on the group as a whole and to Tables II and III for data on colonies from dishes numbered S-6a, S-6b, S-6c and S-6d. Each of these dishes contained one or more colonies, thus accounting for some of the extra numbers found in the various columns in Tables II and III.

Floatoblasts for Group T were removed from the same pint jar containing *Elodea* and water as were those of the preceding groups, where they had remained in liquid for 10.8 months at a comfortable room temperature. They were transferred from that container on Aug. 2, 1941, to a Syracuse watch glass containing tap water. This was the "start" of the experiment. Hence, they were not chilled or dried but remained in liquid at room temperature for the interval between collection and the beginning of the experiment. Five out of 25 floatoblasts germinated. The colonies although in good condition were discarded after nine days because circumstances beyond control made it impossible to care for and daily observe the colonies at that particular time, so the colonies had to be discontinued.

Floatoblasts for Group U were removed from the same pint jar as were those of preceding groups on Aug. 2, 1941, after they had remained in liquid for 10.8 months at room temperature. They then were dried and stored dry in a refrig-

TABLE I

Data on *Hyalinella punctata* Floatoblasts Used in This Study

	Group P			Group Q	Group R Floatoblasts					Group S	Group T	Group U		Group V
	Set P-1	Set P-3	Set P-2		Set R-1	Set R-2	Set R-3	Set R-4	Set R-5			Set U-1	Set U-2	
A. What was done to the floatoblasts before immersion in tap water	Dried 4 days after collection and stored dry at room temperature		Dried 8 days after collection	Dried after long interval of freedom	Chilled then dried soon after collection. Stored in refrigerator					Free for long interval, then chilled and stored in water in refrigerator	Always in water. Stored at room temperature	Free for long interval, then dried, chilled and stored dry in refrigerator		Dried 4 days after collection and stored in refrigerator
B. No. of days floatoblasts were chilled	0	0	0	0	244	263	289	863	632	540	0	306	540	840
C. Temperature ranges at which floatoblasts were kept in refrigerator	—	—	—	—	7-11.2° C.	7-11.2° C.	7-11.2° C.	7-13.5° C.	7-11.2° C.	7-13.5° C.	—	7-13.5° C.	7-13.5° C.	7-13.5° C.
D. No. of days floatoblasts were kept in dry state	289	873	1412	550	227	246	272	846	615	0	0	306	540	840
E. Dates during which floatoblasts remained dry	IX-13-1940 to VI-29-1941	IX-13-1940 to II-3-1943	VIII-16-1937 to VI-29-1941	VIII-2-1941 to II-3-1943	IX-30-1940 to V-15-1941	IX-30-1940 to VI-3-1941	IX-30-1940 to VI-29-1941	IX-30-1940 to I-24-1943	IX-30-1940 to VI-7-1942	—	—	VIII-2-1941 to VI-4-1942	VIII-2-1941 to I-24-1943	IX-13-1940 to I-1-1943
F. Dates during which floatoblasts were in refrigerator	—	—	—	—	IX-13-1940 to V-15-1941	IX-13-1940 to VI-3-1941	IX-13-1940 to VI-29-1941	IX-13-1940 to I-24-1943	IX-13-1940 to VI-7-1942	VIII-2-1941 to I-24-1943	—	VIII-2-1941 to VI-4-1942	VIII-2-1941 to I-24-1943	IX-13-1940 to I-1-1943
G. No. of days from collection till immersion in tap water for start of experiment	293	877	1420	877	248	267	293	867	636	867	327	633	867	844
H. No. of days from immersion to germination	—	—	—	25	2—4	2—6	2—7	4—23	—	1—2	2	6	—	—
I. No. of floatoblasts used	19	20	12	20	37	42	7	36	13	42	25	10	35	14
J. No. of floatoblasts which germinated	0	0	0	10 (?)*	32	35	5	24	0	12	5	1	0	0

K. No. of floatoblasts damaged or imperfect	0	0	0	0	1	4	2	2	0	1	0	0	0	0
L. Temperature ranges at which floatoblasts and their resulting colonies were kept after immersion	24-30.5° C. (average, 27.1° C.)	20.5-31° C. (average, 25.5° C.)	24-30.5° C. (average, 27.1° C.)	20.5-31° C. (average, 26.5° C.)	20.5-30.5°C.	20.5-30.5°C	20.5-30.5°C.	20.5-30.5°C.	20.5-30.5°C.	20.5-31°C. (average, 25.5° C.)	26-28° C.	23.5-26.3°C.	20.5-30.5°C.	23-29.8°C. (average, 26.4° C.)
M. No. of days after germination that first polypides evaginated	—	—	—	—	1—2	1—3	2	1—4	—	2	1—2	8	—	—
N. No. of first polypides evaginated in this group or set	0	0	0	0	32	34	5	23	0	12	4	1	0	0
O. Total no. of polypides drived from each floatoblast-produced colony before its death or discard	0	0	0	0	1	1—2	2	1—500+ See Tables II, III, IV	0	1—18	1	1	0	0
P. No. of days colony or germinated material remained alive after germination	—	—	—	13 (?)*	7†	9—22	3—27†	8—176	—	16—31	7	20†	—	—
Q. No. of days between germination and onset of ancestrula's degeneration	—	—	—	—	6—7	6—12	3—10	5—21	—	12—21	—	—	—	—
R. Fate of colonies	discontinued	discontinued	discontinued	discontinued	discontinued some alive, some degenerating at the time	degenerated	some died, some killed, some discontinued	degenerated	discontinued	one accidentally killed. Rest discontinued	discontinued while alive, before degeneration set in	discontinued while alive, before degeneration set in	discontinued	discontinued

* The 10(?) germinations of Group Q are not exactly normal because although the valves did crack apart and a slight amount of germinative material did appear between them this material did not grow beyond the edge of the valves and produced no visible polypides.

0 Means none or not at all.

— Means there was no data on this, principally because no germinations took place but occasionally for some other reason.

† The † sign after numbers in horizontal line "P" means that some of the polypides could have lived longer if they had not been discontinued for some reason or other.

TABLE II

RATE OF POLYPIDE EVAGINATION AND ANCESTRULA DEGENERATION IN COLONIES OF *Hyalinella punctata* DERIVED FROM GERMINATION OF FG_1

	Colonies in Sets		Dishes Containing Colonies of Set R-4 from Floatoblast Group R								Colonies from Group S Floatoblasts		
	R-2	R-3	R-4a	R-4b	R-4c	R-4d	R-4e	R-4g	R-4h & k	R-4l	S-6a & d	S-6b	S-6c
1. No. days between statoblast immersion and: a. germination	2 to 6 days	2 to 7 days	4 days	5 days	7 days	8 days	9 days	11 days	15, 18 days	23 days	1 day	2 days	1 day
b. evagination of 1st polypide	4 to 7	4 to 9	5	7, 8*	9, 11	9, 12	10 to 13	12	20	25	3	4	3
c. evagination of 2nd polypide	10 to 19	18	14	13, 14*		18 to 23	16, 17	18	26	26	16	21	19 to 21
d. evagination of 3rd polypide			22	15		21 to 26	22, 23	21		28		28	21 to 23
e. evagination of 4th polypide			23	16		25	23	25					23
f. evagination of 5th polypide			23†	17†		26†	24†	25					24 to 26†
2. No. of days between germination and degeneration of ancestrula			21	15	5, 9	16 to 21	11 to 18	13	10	8	12, 13	19	20, 21
3. No. of days between evagination of 1st and 2nd polypides	6 to 12	9, 10	9	6		9 to 14	4 to 6	6	6	1	13	17	16 to 18
4. No. of days between evagination of 2nd and 3rd polypides			8	1, 2		3	5, 6	3		2		7	2, 3
5. No. of days between evagination of 3rd and 4th polypide			1	1		1	1	4					½ to 2

* One of the two colonies in Dish No. R-4b was lost 16 days after floatoblast immersion. Thenceforth the remaining long lived one was referred to as Colony R-4b.

† Further evagination data on these colonies are shown in Table III.

NOTE: Dishes R-2, R-3, R-4b, R-4c, R-4d, R-4e, R-4g, S-6a and S-6c all contained more than one colony at the start, thus accounting for some of the ranges of figures in some of spaces.

erator until needed for experimentation. One June 4, 1942, 306 days later, ten statoblasts, constituting Set U-1, were removed from the refrigerator, immersed in a watch glass containing water and kept at a comfortable room temperature. One of the ten germinated. The resulting colony was discontinued 26 days after immersion while still alive although beginning to degenerate due to improper and insufficient food. The non-germinated floatoblasts likewise were discontinued at the same time. On Jan. 24, 1943, 867 days after collection or after 540 days of desiccation and chilling, 35 floatoblasts, constituting Set U-2, were removed from the refrigerator, immersed in a watch glass containing tap water and kept at room temperature. None of this U-2 Set germinated even though it was kept under observation for 126 days from that time.

TABLE III

RATE OF POLYPIDE EVAGINATION IN *Hyalinella punctata*
(Continued from Table II)

Number of Days Between Floatoblast Immersion and Evagination of the	Colony R-4a	Colony R-4b	Colony R-4d	Colony R-4e	Colony S-6c
	days	*days*	*days*	*days*	*days*
6th polypide	25	18	26, 27	24	24, 26
7th polypide	26	18	27	26	25
8th polypide	26	18	27	26	26
9th polypide	27	18	27, 28	26	26
10th polypide	28	20	28	27	26
11th polypide	28	21	29	27	26
12th polypide	31	21	29	27	27
13th polypide		21	29	27	27
14th polypide		21	29	29	27
15th polypide		21	29	32	27
16th polypide		21	29	32	28
17th polypide		21		35	28
18th polypide		22		35	29
19th polypide		22		35	
20th and 21st		22			
22nd to 26th		23			
27th to 31st		24			
32nd to 45th		25*			

NOTE: Data on Colony R-4b is continued in Table IV.

* This 25 days after statoblast immersion is the same as 20 days after statoblast germination, since there was a 5 days' difference between these two conditions.

Group V consisted of fourteen floatoblasts which were dried four days after collection, then placed in a refrigerator where they remained dry for 840 days, until Jan. 1, 1943, when they were taken out, immersed in tap water and kept at room temperature for 67 days, but no germinations took place so the group was discontinued at the end of that interval. Additional data on this and on the preceding groups may be obtained from Table I.

Originally all the statoblasts of a particular group or set were placed in a watch glass which was labelled with the capital letter of the group and the number of the set, thus: R-4. As soon as any floatoblasts gave the faintest indication of

approaching germination they were removed to another watch glass which would be distinguished from the first by an additional letter after the number, thus: R-4a. When additional floatoblasts of dish R-4 began to germinate another watch glass labelled R-4b would be prepared for the newly germinated statoblasts, and so on. Generally, when several statoblasts germinated on the same day they would all be placed in the same watch glass unless their numbers were so great as to make that confusing or impractical. Such a procedure explains the numerous figures given in column R-4d of Table II, because watch glass R-4d contained a total of nine colonies, some of which had different polypide evagination rates.

Group R furnished some of the most interesting results for the present study because out of its 135 floatoblasts, which were placed in five Sets, R-1, R-2, R-3, R-4 and R-5, 96 germinated and some of them produced long-lived colonies. The R Group consisted of floatoblasts which were placed in a loosely capped vial containing some water in a refrigerator four days after collection. The vial accidentally tipped over, leaving the floatoblasts dry by Sept. 30, 1940, or 21 days after collection. The floatoblasts remained dry in the refrigerator until the beginning of the experiment (please refer to Table I).

Although colonies which developed from the R floatoblasts were very promising material, quite a number of them degenerated too soon because of the food

TABLE IV

FURTHER DATA ON *Hyalinella punctata* COLONY R-4b. THE FG_1 STATOBLAST WHICH PRODUCED THIS COLONY GERMINATED 5 DAYS AFTER IMMERSION

1943 Date	No of days from time of germination to date at left	No of colony fragments	No. of polypides evaginated in any single fragment on date at left		Total No. of polypides evaginated in all fragments on date at left	No of mature floatoblasts released or torn out at given date
			Maximum	Minimum		
II-18 early	20	colony intact	44			
II-18 later	20	2	36	8	44	
II-19	21	2	37	10	47	
II-20	22	2	38+	14	52+	
II-26	28	1	38+	—	38+	2
II-28	30	1	38+	—	38+	1
III- 3	33	1	63+	—	63+	
III- 5	35	1	66+	—	66+	
III-10	40	1	55+	—	55+	
III-12	42	1				5
III-13	43	1				5
III-14	44	1				8
III-15	45	1	Polypides temporarily withdrawn, so can not tell which are alive and which are degenerating. Some degeneration did take place during these intervals.			4
III-16	46	1				13
III-17	47	1				1
III-18	48	1				3
III-22	52	1				1
III-24	54	1	55		55	
III-29	59	1	50		60	
IV- 1	62	1	70		70	
IV- 2	63	1	76		76	

TABLE IV—[*Continued*]

1943 Date	No. of days from time of germination to date at left	No. of colony fragments	No of polypides evaginated in any single fragment on date at left		Total No. of polypides evaginated in all fragments on date at left	No. of mature floatoblasts released or torn out at given date
			Maximum	Minimum		
IV-4	65	1	84		84	
IV- 6	67	1	97		97	1 torn out
IV- 8	69	1	99		99	1 torn out
IV-12	73	2	78	13	91	
IV 13	74	2	76	12	88	
IV-17	78	3	57	14	109	
IV-18	79	6	52	1	110	
IV-19	80	7	45	1	137	
IV-23	84	8	41	6	137	1
IV-24	85	8	33	5	130	3
IV-25	86	8	46	5	150	
IV-26	87	8	51	5	159	1
IV-29	90	8	67	7	189	1
IV-30	91	8	76	11	204	2
V- 1	92	9	92	11	253	1
V- 2	93	9	99	14	288	
V- 3	94	11	100	1	351	
V- 5	96	13	122	1	395	
V- 6	97	14	108	1	365	
V- 7	98	15	120	1	400	
V- 9	100	15	115	1	398	1
V-13	104	10	159	6	471	
V-17	108	11	144	6	491	
V-19	110	14	107	4	434	
V-22	113 *	Progressive degeneration due to food and neglect				4
V-30	121	11	113	1	282	
VI- 3	125	12	87	1	177	1
VI- 8	130	12	68	2	204	
VI-14	136	14	55	2	194	1
VI-17	139	14	38	2	170	2
VI-19	141					8
VI-21	143	13	28	1	136	6
VI-25	147					3
VI-27	149	20	11	1	67	
VI-30	152 *	28	12	1	87	
VII-16	168	14	3	1	21	11
VII-18	170	9			16	
VII-19	171	11			14	
VII-24	176	Colonies or fragments discontinued				1

problem. Set R-1 was fed green algae and other aquarium scrapings but failed to thrive on this diet. Degeneration set in early and the R-1 colonies were discontinued nine days after statoblast immersion. Set R-2 received a similar diet with the same results. Because the R-2 colonies were degenerating they were discarded 26 days after floatoblast immersion. Set R-3 colonies also did not thrive well, some of them degenerating because of green food, others because of lack of food and presence of enemies. Some specimens were discontinued as early as seven days after floatoblast immersion and others as late as 33 days. The colonies were discontinued when still alive when it became evident that degeneration had progressed so far that it was useless to keep them longer. Set R-4 was an unusually productive one, giving rise to a good number of polypides and to some long-lived colonies. Except for one lot which was accidentally destroyed sixteen days after statoblast immersion the colonies lasted a number of days. Some were discarded after a well advanced stage of degeneration on the following days after statoblast immersion: 28, 31, 32, 35 and 51 days. Some colonies fragmented, i. e., polypide groups would become separated from the main body of the colony so that in time there would be a number of living fragments rather than one main colony (refer to Table IV). The longest lived fragments died from lack of adequate care in the final few weeks and from degeneration 181 days after statoblast immersion. This length of time is a record under laboratory conditions. Formerly, in Study III, two *Lophopodella carteri* colonies were kept alive 161 and 163 days after germination while in the present Study the most hardy *Hyalinella punctata* colony and its fragments (R-4b) lived 176 days after germination Both species could probably have lived somewhat longer if it had not been necessary to move them to other localities or if they could have been cared for properly during and after removal. Data on the growth and progress of the long-lived colony R-4b can be found in Tables I, II, III and IV. Set R-5 was discontinued 23 days after the start of the experiment although no germinations took place in it. Table I gives some data on this last Set.

DESCRIPTION OF REARING METHODS

Experimentation on delayed development, on the effects of desiccation, chilling or other factors can best be carried out on statoblasts since these bodies are far hardier and firmer than any other parts of the bryozoan. Statoblasts form and mature within the colony, then may be released soon thereafter or else may be retained within the zoarium after the death and degeneration of the polypides which produced them. Some writers maintain that a rest period is necessary before statoblasts germinate; others doubt it. Statoblasts to be used for the experiment may be dissected directly out of living colonies or may be collected after the colonies had normally released them by expulsion or by division of the colony. The advantage of dissecting them out of living colonies is that one can be sure of their source, particularly if several closely related species are in the same collection. The advantage of allowing colonies to normally shed their statoblasts in the laboratory is that the colony stocks will not be prematurely destroyed, the statoblasts are more likely to be fully mature and finally, much less time is required to collect only shed statoblasts than to dissect them out carefully. All *Hyalinella* statoblasts used in the present study were collected after being normally shed by their colonies. Those used in Set P-2 were collected in Beechmont Lake, New Rochelle, New York, on Aug. 8, 1937. Those used in all the other sets and groups were collected in Westtown Pond, Westtown, Pa., on Sept. 9, 1940. For a more complete description of the collecting sites please refer to Studies IX and XIV.

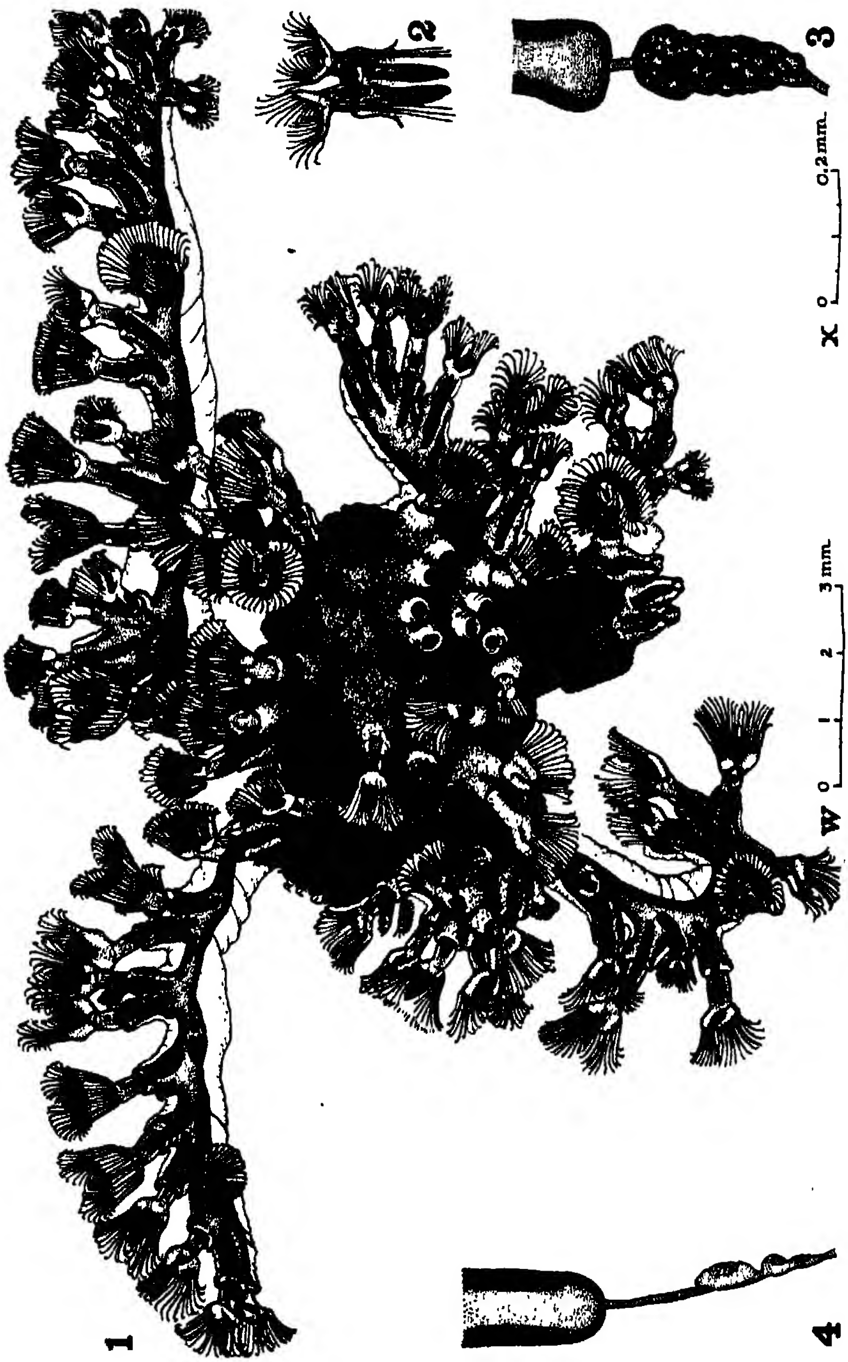
Due to their smaller size floatoblasts of *Hyalinella* and *Plumatella* are less favored for experimentation than those of *Cristatella*, *Pectinatella*, *Lophopus* or *Lophopodella* because they are harder to keep track of or handle.

When an experiment was begun, the dried floatoblasts of a particular group or set were removed from the vials or containers in which they had been stored to Syracuse watch glasses or Petri dishes containing tap water which was later replaced by culture, pond or aquarium water as soon as the statoblasts gave any indication of germinating. This was known as "immersion." However, in the P and V Groups, since no floatoblasts germinated, tap water alone was used. In the other groups tap water was soon replaced by more suitable liquid and food because many statoblasts showed signs of approaching germination.

The specimens were observed once or twice daily with a compound microscope. As a rule dried floatoblasts upon immersion for germination are likely to remain on top of the surface film. When possible they were pushed down with a dissecting needle until they were beneath the surface film. Most of them floated up to the surface film immediately thereafter and remained around the rim of the glass just beneath the film even a number of days after germination.

When the floatoblasts seemed to be near the point of germination tap water was replaced by other water containing food material. The following different foods were tried in some of the sets or groups: green algae (desmids, etc.) from aquarium scrapings, organic debris from the bottom of various culture dishes, tiny ciliates and flagellates, *Paramecia*, small quantities of fresh yeast cake and bacterial scum from culture waters which had one of the following food substances added to them: lettuce, yellow cornmeal, oatmeal, bread crumbs, rice and other cereals. The germinated colonies rejected *Paramecia* but not the very small flagellates and ciliates. The cornmeal and yeast cultures proved the most satisfactory because the colonies seemed to thrive best when these were used, particularly so when small lumps of yeast were placed directly in the dishes containing the colonies. The colonies were maintained on a varied diet rather than on one substance alone because it was found to produce healthier colonies. When colonies began to slow down in polypide production or began to show signs of degeneration the diet was changed because it was more important at the moment to keep the colonies alive than to test the efficacy of the various food products. Additions of small quantities, fragments, of fresh yeast seemed to keep the colonies flourishing The use of the green algae alone had the opposite effect. It caused the colonies either to degenerate after a short time or to slow down their polypide multiplication The slowing down was evident in statoblast development. In some colonies floatoblasts were formed and of fair size and degree of development then failed to carry the developmental process through to completion either because of the degeneration of polypides or for other reasons. Among the most obvious characteristics of degeneration was the stunting effect. The tentacles began to shorten and thicken. The pattern of ciliary action was disrupted. The entire zooid shortened and became smaller. In time the lophophore withdrew permanently. The polypide shortened, thickened and condensed to a brownish-orange colored ball known in literature as the "brown body." In some colonies all the polypides degenerated until there was nothing left but a small bag of coenoecial wall which was progressively reduced in size until it was hard to find among the debris of the dish.

Methods of staving off degeneration were (1) to change the diet if necessary, (2) to keep the colony and the dish in which it was growing as clean as conditions would permit and (3) to aerate the water in the colony dish with a pipette when necessary. Colonies were kept clean of old fecal pellets, debris, scum and other ectocyst-covering accumulations by removing this material with a pipette or by scraping with a dissecting needle or fine forceps. Sometimes this accumulation was so great that it covered the entire colony and had large holes here and there through which the introvert could be protruded, (fig. 1). The accumulation was removed daily when possible. The scraping was done very gently to prevent crushing, puncturing or damaging the colony. Occasionally a colony was constricted or divided by this scummy covering. A colony was sometimes accidentally pulled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apart at this thinned or constricted area without any apparent ill effect on subsequent growth. When that was done, the ends of the broken connection closed up and healed very speedily, provided that the connection was narrow and thin at the time of division. Not only was it the colonies which needed cleaning but also the inner surfaces of the watch glasses and Petri dishes because the debris, stale food, fecal pellets, etc., accumulated at the bottom, generally in the vicinity of the colony. This cleaning was done either by use of a pipette or by emptying most of the water from the dish, hurriedly wiping the inner surface with a clean cloth, taking care not to injure or dislodge the attached colony. Then fresh culture water from a small aquarium and a few tiny lumps of fresh yeast or drops of food culture were added to the dish which contained the bryozoan colony.

OBSERVATIONS

Germination

Within a few days, 1 to 25, after immersion of the various sets or groups of floatoblasts germinations took place in the usual manner. The statoblast valves separated slightly. Between them appeared a bag of tissue containing germinative material and yolk masses. A day or so later, (refer to Tables I and II), the germinated zooid was sufficiently developed to evaginate or protrude a tentacle-bearing lophophore. When evagination had taken place, the distribution of yolk particles was more discernible, (see figs. 5–7). Yolk occurred in extensive masses in the walls of the digestive tract, coenoecium and lophophore. It furnished food for the early developmental stages of the colony. In several instances it had disappeared by the third day after germination while in a few colonies it lasted till the fourth, fifth and even sixth day after germination of the *Hyalinella punctata* statoblasts. In *Lophopodella carteri* the yolk was visible from four to seven days after statoblast germination. Brooks (1929) working with *Pectinatella magnifica* found that the yolk mass had almost disappeared from the *P. magnifica* colonies by eight days (p. 431) and that some young colonies could live for two weeks on the yolk stored in their bodies (p. 435).

Ancestrula

The first zooid to evaginate is known as the ancestrula. In a normal *H. punctata* colony, the ancestrula had a smaller number of tentacles than did successive zooids. Marcus (1941, p 150) observed a similar condition in *Stolella evelinae* ancestrulae. Therefore, a count of the tentacle number was one method of checking whether one was dealing with the ancestrula or with one of its successive

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EXPLANATION OF FIGURES IN PLATE I

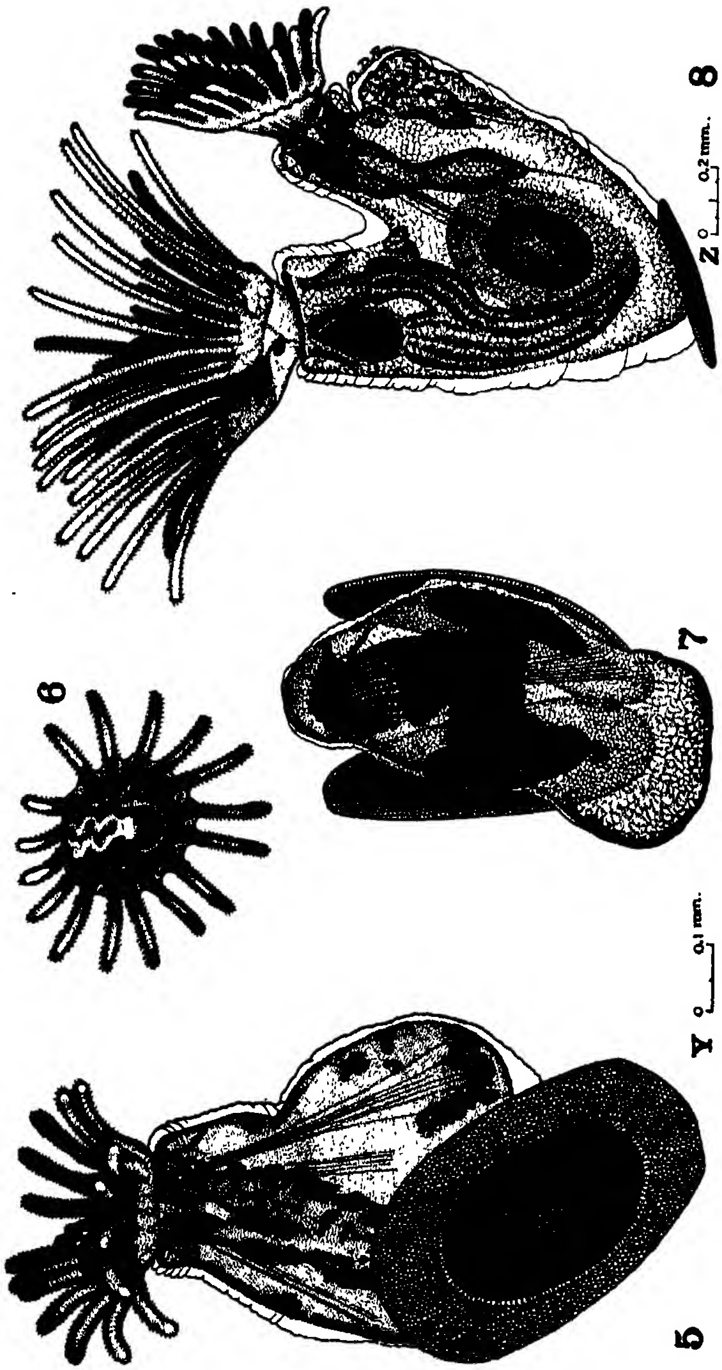
The species depicted in all the figures is *Hyalinella punctata*. All except Figures 2 and 4 were drawn with the aid of a camera lucida.

Fig. 1. Colony R-4b as seen from above on IV–6–1943, or 67 days after germination. The central part of the colony is quite opaque and heavily covered with debris and accumulations so that the zooids in it are hard to see or to count. The transparent ectocyst is best seen around the long branches. The entire colony is attached to the substratum at this time. Drawn to Scale W.

Fig. 2. A diagram of the "twin" polypides as they appeared in Colony R-4b on the 65th day after floatoblast immersion or on III–30–1943. View is of anal side. These polypides were already several days old at this time. Both polypides are using the same invaginated fold and their outer retractors are evident. Not drawn to any scale.

Fig. 3. An immature sperm mass on the funiculus of Colony R-4b's second polypide as seen on II–8–1943 or on the 10th day after germination. Drawn to Scale X.

Fig. 4. Three statoblasts developing on the funiculus of a Colony R-4b polypide. The oldest statoblast is proximal to the tip of the digestive tract. Drawn to Scale X on II–14–1943.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Y 0 0.1 mm.
Z 0 0.2 mm.

buds. The average tentacle number in ancestrulae of 34 *H. punctata* colonies was approximately 28, the maximum number 34 and the minimum 16+. The 16+-tentacled individual had evaginated somewhat prematurely. It had a very small lophophore and short, still poorly differentiated tentacles. The average tentacle number in seventeen normal successive zooids was 44, the maximum 50 and the minimum 32. This last figure was for a very immature polypide which in less than two days increased its number to 44 tentacles. Many more examples than seventeen were observed and counted but because the results were in complete agreement with the figures given above they were not formally recorded. In general it can be said that the average number of tentacles remained smaller in the ancestrula throughout its life span than in the successive polypides although it did increase slightly in both as they matured. For example, one ancestrula which had nineteen tentacles upon evagination added two more within ten hours. Another ancestrula added eight more tentacles to its 24 within four days. Some of the successive polypides likewise added a few tentacles after evagination. In one set of experiments, Colony R-4e, where the food supply was very unsatisfactory, (green food), the colonies and successive polypides were very stunted and the tentacle number was unusually small—sixteen to twenty tentacles. This was an abnormal condition.

The ancestrulae of this study and of Study VIII (p. 208) were the first polypides to degenerate, under normal conditions. The ancestrulae degenerated from 13 to 31 days (average 24.2 days) after statoblast immersion in the case of sixteen colonies and from 8 to 21 days (average 14.3 days) after germination. Some ancestrulae degenerated without giving rise to successive polypides while others survived until the colony had seventeen individuals before degenerating. Those which degenerated early were those which were fed an inadequate or unsuitable food (green algal material) This not only destroyed the ancestrula but the colony as well, sooner than was expected.

The degenerated ancestrulae shrank in size, withdrew into the coenoecium, darkened and either broke up inside or became pinched off. At any rate they

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EXPLANATION OF FIGURES IN PLATE II

Fig. 5. Side view of an S-6a ancestrula as seen on I-27-1943, two days after floatoblast germination or three days after immersion. Large irregular masses of yolk are evident in the wall of the digestive tract, around the base of the long retractor strands and in the endocyst. The ancestrula had only twenty tentacles at this particular time but later increased the number. Only one statoblast valve appears in the diagram. The other valve, not shown here, is directly opposite and hidden by the one pictured. Drawn to Scale Y.

Fig. 6. The tentacular crown of the ancestrula of Fig. 5 as seen from above. The mouth is overhung by a rather small epistome, shown here as a white flap, which enlarges later on. A mass of yolk, the irregular black ring of the diagram, is seen around the bases of the tentacles at this early stage but later disappears. It is also present around the epistome but could not be shown here conveniently. The tentacles number 20, increased to 24 one day later (I-28-1943) and to 28 by the day following. Drawn to Scale Y.

Fig. 7. A small retracted R-4e Colony drawn one day after germination or ten days after immersion. A very small amount of yolk is seen dispersed in the basal endocyst region. A large yolk mass, (dark central irregular mass in the center of the diagram), appears around the digestive tract while a smaller amount is seen directly above, in the invaginated fold region. Statoblast valves appear on either side of the germinated colony. Drawn to Scale Y.

Fig. 8. Side view of Colony R-4b. Drawn on II-6-1943 or eight days after germination or thirteen days after immersion. The larger of the two evaginated polypides is the ancestrula. It has ±32 tentacles but not all can be seen from this view. The second or smaller polypide has 40 tentacles differentiated at this time. The two statoblast valves are shown, one in full-face view at center back and the other in partial edge view at the base of the colony. The retractors and funiculus of the ancestrula have been omitted. Drawn to Scale Z.

disappeared within a few days. Polypides other than the ancestrulae degenerated in the same manner. The rate of degeneration and the time factor in their case however has not been studied.

Successive Polypides

Buds formed and evaginated at a rapid rate when the food was adequate and suitable. To estimate the rate of bud formation it would have been more desirable to record the initial appearance of each bud germ or rudiment but from the practical point of view it proved less satisfactory and less easy than the method adopted, namely: noting the time when the bud had developed sufficiently to evaginate and take external food. In large colonies or in those covered with debris and various accumulations it was very hard to see buds forming and often those which were present might be mistaken for other things in a crowded colony. Bud formation and development in *Hyalinella* was very similar to the bud formation of other Plumatellidae. Buds at the time of evagination were well developed although small and short. Their lophophores were rather immature in that not all the tentacles had differentiated sufficiently from each other and from the substance of the lophophore to be easily counted.

The time interval between evagination of the ancestrula and the second polypide is generally slightly longer than the intervals between other pairs of successive polypides. It ranged from one to eighteen days. The interval between evagination of the second and third polypides was from one to eight days, while between the third and fourth polypides it was from one-half to four days. The interval between evagination of the fourth and fifth zooids was from a few hours to three days while the interval between emergence of the fifth and sixth was from a few hours to one day. From the sixth polypide onward the intervals were shorter and shorter, as a glance at Tables II and III will show. The reason for this was that a number of buds were forming then maturing at approximately the same time.

The time interval between statoblast immersion and the evagination of the second polypides in colonies of Table II was from 10 to 26 days or averaged 17.7 days for 31 colonies. The interval between statoblast immersion and evagination of the third polypides was from 15 to 28 days. For the fourth polypides it was from 16 to 25 days; for the fifth polypides 17 to 26 days; for the sixth, seventh and eighth it ranged from 18 to 27 days; for the ninth it was from 18 to 28 days; for the tenth it was from 20 to 28; for the eleventh, thirteenth and fourteenth it was from 21 to 29; for the twelfth it was from 21 to 31; for the fifteenth and sixteenth polypides it was from 21 to 32 and for the seventeenth from 21 to 35 days after statoblast immersion. Tables II and III show some of this data.

R-4b Colony

The time interval for evagination of *Hyalinella* polypides beyond the nineteenth polypide was based on data obtained from one of the colonies of Dish No. R-4b and is shown in Table III. This colony's twentieth and twenty-first polypides evaginated on the 22nd day after statoblast immersion. Its twenty-second to twenty-sixth polypides evaginated on the 23rd day, its twenty-seventh to thirty-first polypides evaginated on the 24th day, its thirty-second to forty-fifth polypides evaginated on the 25th day. By the evening of the 25th day, the dish containing the R-4b colony was accidentally dropped and the colony was torn into two separate pieces, one fragment with 36 polypides and the other with 8. The ancestrula which began to degenerate five days previously accounts for the forty-fifth polypide.

Up to this time, the only individual of this particular colony in dish R-4b to degenerate had been the ancestrula and observations of the inner contents of the colony had been easy. Now, after the accidental separation of the colony, counting of polypides and degenerate individuals became more difficult because the larger

fragment was no longer attached to the substratum but had become a ball-shaped mass from which polypides protruded in all directions. For that reason, for several days thereafter polypide counts of the larger fragment were only approximate. The polypide counts of the smaller fragment were easy and accurate because that part of the original colony fortunately had not been torn loose from the substratum at the time of the accident. That fragment evaginated two additional polypides the next day and four more the day following, making a total of fourteen nicely evaginated buds. The third day after the tearing of the original colony the two fragments were still evaginating additional buds but degeneration had set in in some of the polypides, four in the smaller fragment and several in the larger. By the seventh day after the tearing all polypides of the smaller fragment were dead while the larger fragment was getting along apparently fairly well and had between 28 and 38 polypides nicely evaginated. The number is uncertain because 28 could be definitely counted from one view and there were a number on the other side which could not be counted accurately but were estimated to be about 10. From this time on there was a steady increase in the number of evaginated polypides which could be counted but the colony fragment remained unattached until the 52nd day from the time of statoblast immersion or the 27th day after the tearing of the colony.

In Colony R-4b there was noted on the 60th day after germination a rather rare and unusual pair of well-developed, evaginated polypides, twins, sharing a joint invaginated fold but having a partially or slightly separated tentacular sheath and so far as could be ascertained, one set of retractors on each side, moving both polypides as a unit in and out of the coenoecial sac (fig. 2). The twins evaginated, invaginated or unfurled their tentacles simultaneously, moving or acting as a unit. When one was disturbed with a dissecting needle both retracted and after recovery both evaginated as one. They were crowded together rather closely, side by side, but seemed very vigorous Their digestive tracts were separate and complete but so close together that one could not determine if there were any retractor muscles between them. The tentacle sheath was larger than normal and so was the diameter of the duplicature or invaginated fold. The twins were still functioning nicely five days later. After that they were lost sight of because of the large number (84) of polypides in the colony at that time and because degeneration set in in some parts of the colony, resulting in masses of debris here and there over the colony. It is very probable that the twin polypides degenerated prematurely. At any rate they could not be found after that. These polypides were well developed, mature and several days old when first observed. One of the reasons why they had passed unnoticed up to that time was because of the large number of polypides evaginated in the colony at that particular time.

It would have been ideal to have been able to study a colony from germination through evagination and degeneration of every formed zooid. That would be an almost impossible feat under even the most ideal conditions in view of the fact that colonies may consist of hundreds of crowded individuals and may sometimes be opaque enough in some regions to make observations unsatisfactory.

After the R-4b Colony was torn in two and its larger fragment curled up into a ball or bag of evaginated polypides, (this was between the 20th and 47th day after germination of the colony or between the 25th and 52nd day after immersion of the original floatoblasts), it was no longer possible to count with any great accuracy the exact number of polypides which degenerated and evaginated during that interval. All that could be done with reasonable accuracy was to count the number of polypides which had their tentacles evaginated at any one given moment and to record this number. This means that identical counts for successive days or any days may be variously interpreted. They might mean that no change had taken place in the colony or they might mean that several polypides had degenerated and an equal number of new buds had evaginated their lophophores at about the

same time so that the count would seem identical. Table IV shows the number of polypides which had their tentacles out at the time of counting and does not take into consideration the number of polypides which had degenerated. The greatest number of *H. punctata* zooids "out" or evaginated at any one time was 491 in the aggregation of R-4b colony fragments. The largest number of *Lophopodella carteri* zooids out at any one time was 45 (Rogick, Study III, p. 462).

The larger of the two original fragments of Colony R-4b continued its development until the 73rd day after germination when it had 91 polypides in the evaginated state and 15 withdrawn, degenerating polypides. It then fragmented into two pieces, one with 13 polypides out and the other with 78 polypides out. From here on fragmentation continued until eventually, on the 152nd day after germination, there developed from the original fragment 28 colony fragments, several of which contained only a single polypide each. Many of these fragments had been the result of too fast growth of zooecial branches in various directions away from the colony center, followed by degeneration of some of the intermediate polypides or areas between branches. Others of these fragments have been the result of accidental severing from the colony during the cleaning process which consisted of scraping away debris or pellet accumulations or degenerated material from the ectocyst.

The fragmentation phenomenon is not a new thing. It has been found in other bryozoan species: in *Stolella evelinae* by Dr. Marcus (1941, pp. 92, 150), in *Lophopodella carteri* by the writer (1935, p. 462) and very probably in other species by earlier workers. In general, the maximum number of fragments of Colony R-4b in existence at any one time was 28 and the maximum number of polypides evaginated in one fragment at a particular time was 159. For a more detailed account of the number of fragments and the maximum and minimum numbers of evaginated polypides in the fragments please refer to Table IV.

The fragmentation was most pronounced after the culture water had become too rich. Also at such times the amount of degeneration was quite considerable. In general the change from spoiling culture water to fresher media with the addition of a small amount of fresh yeast was the signal for accelerated polypide development and evagination. Examples are shown in Table IV; for example: fresh culture water and yeast were added to the colony fragments on the 97th day after germination and the very next day the number of evaginated polypides was 35 more than on the previous day. Another example of colonies speeding up polypide production and evagination was when fresh culture water and yeast were added to the colonies on the 101st day after statoblast germination, then every other day practically for about a week, until the number of evaginated polypides had risen from 395 on the 101st day to 491 polypides on the 108th day after statoblast germination, or the difference of 96 polypides in seven days. Sometimes, however, the addition of yeast did not arrest degeneration.

Too much or too little food, lack of care, neglect, rough handling, puncture or injury with dissecting needle and failure to keep culture water reasonably fresh contributed greatly to degeneration of polypides. See data from April 8 to 13 and from May 17 to July 19 in Table IV. After a colony began to show signs of regression, the dish was cleaned and fresh culture water and yeast were added to try to bring the colony back to normal. After such treatment there was some "revival" of the colony or an increase in the number of polypides, as data from May 9 to 17, from June 3 to 8 and from June 27 to 30 in Table IV show. The colonies were packed for transfer from New Rochelle, N. Y., to Woods Hole, Mass., on June 30 and received very little attention or care after transfer till the degeneration of the various fragments of the colony on July 24. Perhaps, if it had been possible to properly care for the colony fragments during the interval they might have survived for a considerably longer period.

Polypide Degeneration

The polypide degeneration rate was greatly influenced by improper food, fouling of the culture water, accidental injury and the presence of enemies like rotifers and oligochaetes.

Table V gives the degeneration data for various groups, sets or colonies. It indicates when the first definite signs of degeneration appeared rather than the day when the polypides actually died. Sometimes there was a difference of one to four days between onset of degenerative processes and eventual death of a polypide, and a difference of three to seven days between onset of degeneration and complete disappearance of the polypide.

TABLE V

DEGENERATION RATE OF POLYPIDES

Group or Dish or Colony Number	Polypide Number	Number of Readings, 1 per polypide	Number of days from immersion to degeneration of that particular polypide		
			Maximum	Minimum	Average
R-1	ancestrula	28	10	9	9 1
R-2	ancestrula	29	15	8	11 6
R-3	ancestrula	5	17	5	9 8
R-4	ancestrula	18	31	12	23 7
S-6	ancestrula	12	22	12	15 4
R-2	second	11	26	13	19 4
R-3	second	2	30	30	30 0
R-4	second	14	31	22	27 9
S-6	second	5	29	23	26 0
R-4	third	7	32	26	30 0
S-6	third	2	29	27	28 0
R-4e	fifteenth	1	37	37	37 0
R-4e	sixteenth	1	43	43	43.0
R-4e	seventeenth to nineteenth	1 each	49	49	49 0

In Sets R-1 and R-3, the food was unsuitable and caused the early degeneration of the first zooids and prevented the colonies from developing many polypides. The same was true for colonies in dishes R-4a, R-4c, R-4d and S-6. At times some factor or combination of factors would cause the simultaneous degeneration of several polypides in the colony.

Broadly speaking, the ancestrulae or first polypides degenerated from 5 to 31 days after floatoblast immersion or from 3 to 21 days after statoblast germination. The second polypides degenerated from 13 to 31 days, the third polypides from 26 to 32 days and the fourth polypides from 27 to 33 days after floatoblast immersion. It is quite possible that the maximum number of days given in Table V is shorter than it would have been had food and other growth conditions been better.

Rather unexpectedly, the longest lived colony, R-4b, furnished the least accurate data on polypide degeneration, largely because it was accidentally torn in two on the 25th day after floatoblast immersion and because of its subsequent fragmentations. Up to that time, the 25th day after floatoblast immersion, only one polypide, the ancestrula, had degenerated. Its degenerative processes had set in or begun five days previously. Thenceforth, it became difficult to tell

which polypide was the second, third, fourth, etc. Moreover, the larger fragment had developed an opaque surface, was unattached and in the shape of a ball for some time after that, so that accuracy in recording degeneration of successive polypides was impossible. Therefore no reliable record was obtained of degeneration of polypides from the 25th day after floatoblast immersion for this particular colony.

In some colonies the ancestrula was the only polypide to evaginate and degenerate. In other colonies a number of polypides, even as many as fourteen, were produced and evaginated before the ancestrula showed definite signs of degeneration.

New Terms

The entire foregoing account of germinating statoblasts was based on a floatoblast generation which had originated or was produced outdoors, under natural conditions, before collection. For reasons which will soon be apparent it was necessary to distinguish the various generations of statoblasts which were produced by assigning to each generation a symbol or name so that it would be possible to refer to each generation specifically. Since the ordinary genetics terms P, F_1, F_2, etc., are inadequate for this type of life cycle which includes several modes of reproduction as the sexual, budding, floatoblast and sessoblast methods it is suggested that the following new terms be used for a part of the life cycle and that others be introduced later as urgent need for them arises and when more is known of the life cycles of some of these forms. The floatoblasts which were begun or produced in the ponds or lakes before collection and which were brought indoors to start new colonies were designated by the symbol "FG_1" which means "Floatoblast Generation Number One." The immediate colonies produced by their germination were called "FG_1-produced colonies." When the FG_1-produced colonies formed a new generation of floatoblasts these new floatoblasts were called "FG_2" or "Floatoblast Generation Number Two." When they in turn germinated and gave rise to colonies the latter were called "FG_2-produced colonies." A new generation of floatoblasts arising from the FG_2-produced colonies would be called "FG_3," etc.

FG_2 Development

The floatoblasts used in Groups or Sets of P, Q, R, S, T and U were all FG_1. The colonies some of them elaborated and on which Tables I to V are based, were FG_1-produced colonies. In time, on the funiculi of their polypides appeared FG_2 (floatoblast) Anlagen, rudiments or "germ" (Fig. 4). In this species, *H. punctata*, the usual number of rudiments was two per funiculus although the number occasionally was greater, other times less. In a recently examined *Plumatella repens* var. *fruticosa* colony the number of statoblast rudiments on one funiculus was fourteen, the most mature one being closest to the caecal end of the digestive tract and the youngest one being most distally located with respect to the tract.

The *H. punctata* floatoblast rudiments appeared on funiculi of evaginated buds and also on those of buds which were so small and immature that even their tentacles were not yet clearly defined nor evaginated. The rudiments were lumps of very small size on the funiculus when first noted.

The first FG_2 (floatoblast) rudiments were evident 13 days after germination of Colony R-4e, 16 days after germination of Colony R-4b and 24 days after germination of Colony R-4d, or, if time is reckoned from the date of FG_1 immersion rather than from colony germination then the floatoblast rudiments (FG_2) were first noted 21 days after immersion in Colony R-4b, 22 days after immersion in Colony R-4e and 25 days in Colony R-4d. No FG_2 rudiments appeared in Colony R-4a even by the 32nd day after immersion of FG_1, (or by the 28th day after germination of the colony), although by that time the colony had produced twelve

polypides. The number of polypides which had evaginated by the time the first floatoblast rudiments made their appearance was three in Colony R-4e, four in Colony R-4d and seventeen polypides in Colony R-4b. These floatoblast-Anlagen appearance and formation figures for *H. punctata* are similar to those given by the writer for *Lophopodella carteri* (Study VII, p. 194, 13 to 59 days after germination) and somewhat larger than figures given by Dr. Marcus for *Stolella evelinae*. Marcus stated (1941, p. 150) that, "Statoblasts (of *S. evelinae*) occur as early as in the funiculus of the second or third individual of a statoblast colony," and that "the formation of a statoblast takes 8 days."

Sometimes the development of FG_2 (floatoblast) rudiments proceeded to completion. Other times degenerative processes set in and the rudiments failed to continue their development. Roughly speaking, floatoblasts seemed to be produced in series but it was difficult to tell when one series ended and another began, particularly since colony degeneration set in now and then because of improper food or other condition and because new statoblast rudiments did not appear simultaneously over the colony. With the alleviation of some of these conditions the life of the colony was prolonged and new floatoblast rudiments got a chance to form while frequently some of the previously begun statoblast rudiments disappeared. Therefore it was best to place the data in Table IV, rather than to attempt to number the various series of statoblasts which were produced. For example, Colony R-4b produced varying numbers of statoblasts whose rudiments were first noted on the following days: 21, 39, 67, 87, 91 and 135 days after immersion of the FG_1.

When colonies containing developing statoblasts in advanced stages of maturity or brownness fragmented, some fragments eventually lost all their polypides through degeneration and became mere coenoecial bags containing floatoblasts while other fragments continued their development after recovery. The polypide-less sacs gradually decreased in size but the brown statoblasts remained inside until dissected out with needles. One such polypide-less sac contained an immature floatoblast which continued its development to a slight extent but had almost no float although its capsule was pretty well developed.

In Colony R-4b, the first two floatoblasts of FG_2 were released 12 days after their rudiments were first noticed in the colony. A third statoblast was released 14 days after first being noticed and forty statoblasts were released between 26 and 36 days after first notice of their rudiments. Table IV, last column, shows some of this data and more also. The floatoblasts when released sank to the bottom of the dish.

A total of 92 floatoblasts (FG_2) were released by Colony R-4b, mostly normally but a few with the aid of dissecting needles. These floatoblasts were divided into several groups for further study. One group was set out immediately after release, to germinate. Another group was dried and stored dry in vials at room temperature. A third group was dried and stored thus in the refrigerator. A fourth group was stored in a small quantity of tap water in the refrigerator. All but three floatoblasts of the first FG_2 group of twenty-one which had been set out to germinate immediately after release or dissection from the parent colony R-4b did hatch. Their germination occurred between 13 and 35 days (average 27.5 days) after removal from parent colony or its debris. They had been in water all the time from release from the colony and had not been subjected to chilling or drying. The other three groups have been set aside for future experiments.

Sperm Development

Thus far asexual reproduction of two types, by budding and by floatoblasts, has been discussed. The early stages of sexual reproduction, particularly sperm production, were visible for a brief interval of five or six days in Colonies R-4a and R-4b respectively. Spermaries appeared as irregular, lumpy, granular masses

on the funiculus of both evaginated and as yet unevaginated buds but for some reason were not found on the funiculus of the ancestrula in the colonies under observation. After a short time the sperm masses looked rather massive and hairy, the sperms making a squirming, undulating hairy covering over a large part of the funiculus. Later still long, slender, hair-like sperms could be seen circulating about in the body cavity. This latter condition prevailed five or six days after the spermaries were first noticed. It also marked the end of the spermary as a visible mass. Sperm masses formed very speedily and were noticeably well developed in Colony R-4b by the 10th day after germination, in Colony R-4a by the 18th day after germination and in Colony R-4d before the 24th day after germination. They appeared sooner than floatoblast rudiments in these colonies.

CONCLUSIONS

Hyalinella punctata floatoblasts were divided into several groups. Each group was kept under a slightly different set of conditions. The highest percentage of germinations, 71.1%, occurred in the R Group of 135 floatoblasts which had been placed in a refrigerator in liquid. After a while there they had become dry and were stored dry at the same low temperatures (7–13.5° C.) from 244 to 863 days. The R Group furnished the longest lived colony of any other group. Groups S floatoblasts which had been stored wet in a refrigerator for 540 days, after a long period of freedom in water at room temperature showed a slightly higher percentage of germinations, 28.5%, than Group T floatoblasts which had been stored in water at room temperature for 327 days (25% germinations).

Considering the difference in age of the statoblasts this percentage difference assumes more value. S and T Groups both showed higher percentages of germination than did Group U, 2.2%, which consisted of floatoblasts which had remained free indoors in water for a long time at room temperature, then were dried and stored in a refrigerator at from 7° to 13.5° C. for 306 to 540 days. The poorest showing as regards germinations was made by Groups P and V, neither of which produced any. Floatoblasts of both groups had been dried a few days after collection. Those in Group P were then stored dry at room temperature from 289 to 1412 days while those of Group V were stored dry in the refrigerator for 840 days. The Q Group, consisting of floatoblasts which had remained indoors at room temperature throughout a long interval of freedom in liquid followed by a 550 day interval in the dry condition, gave rather odd results. Although there was a 50% germination (?) or more precisely a splitting apart of the valves of half of the statoblasts no polypides evaginated or were visible. Therefore it was hard to compare this group with the others.

Based upon the foregoing results it would seem that the least satisfactory method of keeping *Hyalinella punctata* floatoblasts alive for future germinations would be to dry them soon after gathering then store them dry at room temperature. This method, however, proved very satisfactory for *Lophopodella carteri* some of whose floatoblasts retained their viability for after four and one-quarter years in the dry state at room temperature (Study XI, p. 318). Unfortunately, no *Lophopodella carteri* floatoblasts were stored in the refrigerator for any considerable length of time so that a comparison between viability retention through drying and through chilling can not be made at the present moment for that hardy species. A more satisfactory method for keeping *H. punctata* statoblasts viable was to place them for a few weeks in a refrigerator, allowing them to become dry there and to remain there at temperatures between 7° and 13.5° C. until ready for use. *Hyalinella punctata* statoblasts so treated remained viable 867 days after collection and produced good colonies. The upper limit of viability has not been reached for *H. punctata* floatoblasts so treated.

To begin germination experiments, floatoblasts were removed from their storage places and placed in shallow dishes partly filled with tap water and there left until germination occurred.

After the floatoblasts germinated the resultant colonies were fed by various foods: bacteria, algae, Protozoa and organic debris from various food products. Addition of small quantities of fresh yeast to the Bryozoan culture proved very beneficial, both as a growth stimulant and as a means of helping to prevent degenerative processes from coming to a too speedy culmination.

Although rearing conditions were not always most satisfactory, nor was the food always the most suitable, nor the cultures always free from Bryozoan enemies, nor the colonies always hardy, it was still possible, because of a great deal of care and attention, to keep some of the *H. punctata* colonies and fragments alive 176 days after floatoblast germination, a longer time than has been recorded for any other fresh-water Bryozoan species to date.

Out of 323 variously treated *Hyalinella punctata* floatoblasts which were immersed in water for purposes of germination, 124 hatched in one to twenty-five days after immersion. Of these 124 germinations, 111 evaginated first polypides or ancestrulae in one to eight days after germination, thirty-nine evaginated second polypides, sixteen evaginated third polypides, eleven evaginated fourth polypides, ten protruded fifth polypides, eight evaginated sixth, seventh and eighth polypides, seven evaginated ninth zooids, six evaginated tenth zooids, five evaginated up to twelve polypides, four evaginated up to sixteen polypides, three up to the eighteenth polypide, two evaginated nineteenth polypides and one, the long-lived colony and its fragments produced and evaginated more than 500 polypides. Because of the colony's tendency to fragment or divide into several smaller colonies not all the 500^+ polypides derived from the germination of one floatoblast were in one mass but were distributed among several colony fragments. At one time there were as many as twenty-eight colony fragments from the one statoblast and at another time there were as many as 159 polypides evaginated in a single fragment The time interval for evagination of each series of polypides, first, second, third, etc., is given in detail in the "Successive Polypides" section and Tables II and III

Extensive study of polypide degeneration was not made except in the case of the ancestrula. The ancestrulae, which were generally the first to degenerate, began to do so from three to twenty-one days after floatoblast germination. Data on degeneration of some successive polypides is also given in the text of the article

Because of the long life span, studies on (a) the rate of polypide addition, degeneration, formation of sperms and of a new floatoblast generation and (b) the manner of growth, behavior and other bodily or colonial processes were possible The general developmental and colonial processes were similar to those of *Lophopodella carteri* although the rate or time interval for the various processes differed somewhat.

Sperm masses appeared early, from ten to twenty-four days after statoblast germination and lasted a very short time, for five or six days. A new generation of floatoblasts was first noticed developing from sixteen to twenty-four days after germination of their parent floatoblasts. Some of these new floatoblasts matured and were released from the colony as early as twelve days after their Anlagen were first observed while others took longer, some as long as thirty-six days. The total number of new generation (FG_2) floatoblasts obtained from the longest lived colony was 92, some of which were put aside for future germinations and some of which germinated between thirteen and thirty-five days after release from the parent colony.

The new symbols and expressions FG_1, FG_1-produced colonies, FG_2, FG_2-produced colonies, FG_3, etc., were introduced to distinguish between the various generations of statoblasts and colonies derived from their germination. The FG_1 stands for the First Floatoblast Generation (that used to start this particular

experiment). The colonies derived from it were called FG_1-produced colonies. They in turn produced a new floatoblast generation known as FG_2. The colonies which germinated from this new generation of floatoblasts were called FG_2-produced colonies. These in turn gave rise to a third generation of floatoblasts known as FG_3, etc. The terms will simplify reference to any particular generation.

SUMMARY

1. *Hyalinella punctata* floatoblasts, collected from two localities, New Rochelle, N. Y., and Westtown, Pa., were used in these experiments.

2. The "age" of the 323 floatoblasts used, counting from the time of collection of the mature floatoblast to the time of its immersion in shallow dishes partly filled with tap water for purposes of germination, ranged from 248 days to 1420 days. Germinations were obtained from those whose "age" ranged from 248 to 877 days but not from those of 1420 days. The failure of the last to germinate was due perhaps not so much to age as to the method of storing them (dried and at room temperature). Those which did germinate had been stored under slightly different conditions,—some involving chilling, some storing while wet, some drying after long wet intervals, etc. For greater details see Table I.

3. Out of the 323 variously treated floatoblasts, 124 hatched, 111 of these evaginated ancestrulae, 39 evaginated second polypides and a progressively smaller number evaginated larger numbers of successive polypides up to the nineteenth polypide. From the twentieth polypide on, only one colony (which fragmented many times) continued its development.

4. The longest lived colony produced more than 500 evaginated polypides, at one short period was divided into as many as twenty-eight separate fragments and produced 92 mature floatoblasts, some of which hatched and some of which were stored for future experiments. It also produced sperms. Some of its fragments lived till the 176th day after the germination of the original floatoblasts or till the 181st day after their immersion. This length of time is a record for any statoblast-derived Bryozoan colony kept under laboratory conditions.

5. Because of these germinations and the progress of some of the colonies it was possible to obtain definite information on the rate of formation and degeneration of polypides, the time of appearance and rate of formation of new statoblasts and sperms, the habits of colonies and individuals, the manner of rearing and keeping colonies and statoblasts. Much of this data is embodied in the several tables of the article.

6. Several new symbols and terms are introduced to distinguish the various generations of floatoblasts and the colonies derived from them: FG_1, FG_1-produced colonies, FG_2, FG_2-produced colonies, FG_3, etc.

7. Included also is a small glossary of terms pertaining to fresh-water Bryozoa.

GLOSSARY OF FRESH-WATER BRYOZOAN TERMS

ANCESTRULA—This is the primary or first individual of a colony. It comes from between the valves of a germinating statoblast, to elaborate a colony. In marine Bryozoa it has a slightly different origin.

BUD—This is an individual produced by the proliferation of cells in a definite part of the body wall of an individual of the colony.

CAPSULE—This is the darker colored, usually brown, part of a statoblast enclosing the germinative material.

COENOECIUM—This is the name given the common dermal system of a colony by Allman and includes the ectocyst and endocyst.

DUPLICATURE—This is the fold of body wall around the base of the tentacle sheath or introvert when the polypide is evaginated. It is also known as the sigmoid fold and as the invaginated fold.

ECTOCYST—This is the outer of the "two" layers of the body wall. It may be one or more of the following: thin, thick, delicate, firm, soft, swollen, gelatinous, transparent or hard, crusty, deeply colored (yellow to brown or reddish brown) depending upon the genus and species.

ENDOCYST—This is the inner of the "two" layers of the body wall. In reality it is not a single layer but may consist of several layers as shown by Dr. Borg and others.

EVAGINATION—This is the act of protrusion of the introvert or tentacular crown and tentacular sheath from the coenoecium.

FG_1—The first or parent generation of floatoblasts used in a set of germination experiments. Defined in present Study.

FG_1-PRODUCED COLONIES—These are the colonies derived from the germination of the FG_1 (floatoblasts).

FG_2—Floatoblast generation No. 2, developed from the FG_1-produced colonies.

FG_2-PRODUCED COLONIES—Colonies derived from the germination of FG_2 (floatoblasts).

FG_3—Floatoblast generation No. 3, developed from the FG_2-produced colonies.

FLOAT—It is that part of the statoblast known as the "cellular" annulus. It covers part of the capsule and usually extends beyond it.

FLOATOBLAST—This is elsewhere known in literature as a free or floating type of statoblast which does not possess spines or barbs or hooked processes. Defined more fully in Study XIV.

FUNICULUS—This is the cord of tissue attaching the digestive tract to the body wall. From it develop the floatoblasts of the Phylactolaematous Bryozoa.

GERMINATION—This is the splitting apart of the two valves of a floatoblast to permit the further growth of the germinative material or preformed polypides which are within the capsule.

INTROVERT—That part of the polypide which is evaginated and which begins in the region of the duplicature. It includes the tentacular crown and tentacular sheath.

INVAGINATION—The withdrawal, either temporary or permanent, of the polypide into the body cavity.

LARVA—The sexually produced, free-swimming ciliated stage in the life cycle.

LOPHOPHORE—This is a horseshoe-shaped or circular ridge on which are borne the tentacles

POLYPIDE—Prouho (in Borg, p. 190) defines it as a single word or unit comprising the organs of digestion and muscular activity of an individual. It refers to the soft parts of an individual and includes the tentacular crown.

RETRACTORS—The large bundles of muscles attached to the lophophore and to the upper part of the digestive tract which are concerned with pulling the polypide in during invagination.

SESSOBLAST—A statoblast which was formerly called sessile, fixed or attached. Term defined in Study XIV.

SPINOBLAST—This is a floating or free statoblast which is provided with spines, barbs or hooked processes. It is more fully defined in Study XIV.

STATOBLAST—A hard chitin-walled body or gemma of various but characteristic shapes produced in large numbers by many fresh-water Bryozoa. It contains within its capsule germinative material which is capable of producing a colony when conditions are suitable for its germination.

TENTACULAR CROWN—Consists of the lophophore and its tentacles

TENTACULAR SHEATH—That part of the introvert which encloses the tentacles when the polypide is invaginated.

ZOARIUM—Refers to the colony of the Bryozoan.

ZOOECIUM—The external skeleton or remains of the firmest part of the body wall of an individual of a colony.

ZOOID or ZOID—Any one of the living individuals of a colony.

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A NEW SPECIES OF AGRILUS FROM KENTUCKY

(Buprestidae: Coleoptera)

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Agrilus cladrastis n. sp

Male—Size and form of *A. celti* Knull, uniformly dark bronze; legs with greenish lustre; head metallic green on front.

Head convex, granulose on front, finely longitudinally rugose on occiput, clothed on lower half with dense white pubescence; antennae extending beyond middle of prothorax when laid along side, serrate from fifth joint.

Pronotum wider than long, narrower at base than at apex; sides subparallel in front, strongly narrowed basally; when viewed from side, marginal and submarginal carinae separated in front, united near base; anterior margin sinuate with broad median lobe; basal margin transversely sinuate; disk convex, with two slight median depressions, a deep lateral depression each side near margin, prehumeral carina on each side well marked. Scutellum transversely carinate.

Elytra wider than base of pronotum; sides subparallel basally, constricted about middle, widened back of middle, then narrowed to rounded serrulate apices; disk feebly longitudinally depressed, sutural margin elevated posteriorly, a broad basal depression on each elytron; surface imbricate.

Abdomen beneath finely punctate, pubescence inconspicuous, first two segments flattened in middle, slightly concave. Prosternal lobe broadly rounded in front, broadly emarginate at middle. Posterior coxa with hind margin broadly emarginate, outer angle rectangular Anterior and middle tibiae mucronate on inner margin at apex. Posterior tarsi shorter than tibiae. Tarsal claws similar on all feet, cleft, outer tooth long, acute; inner tooth broad, very short.

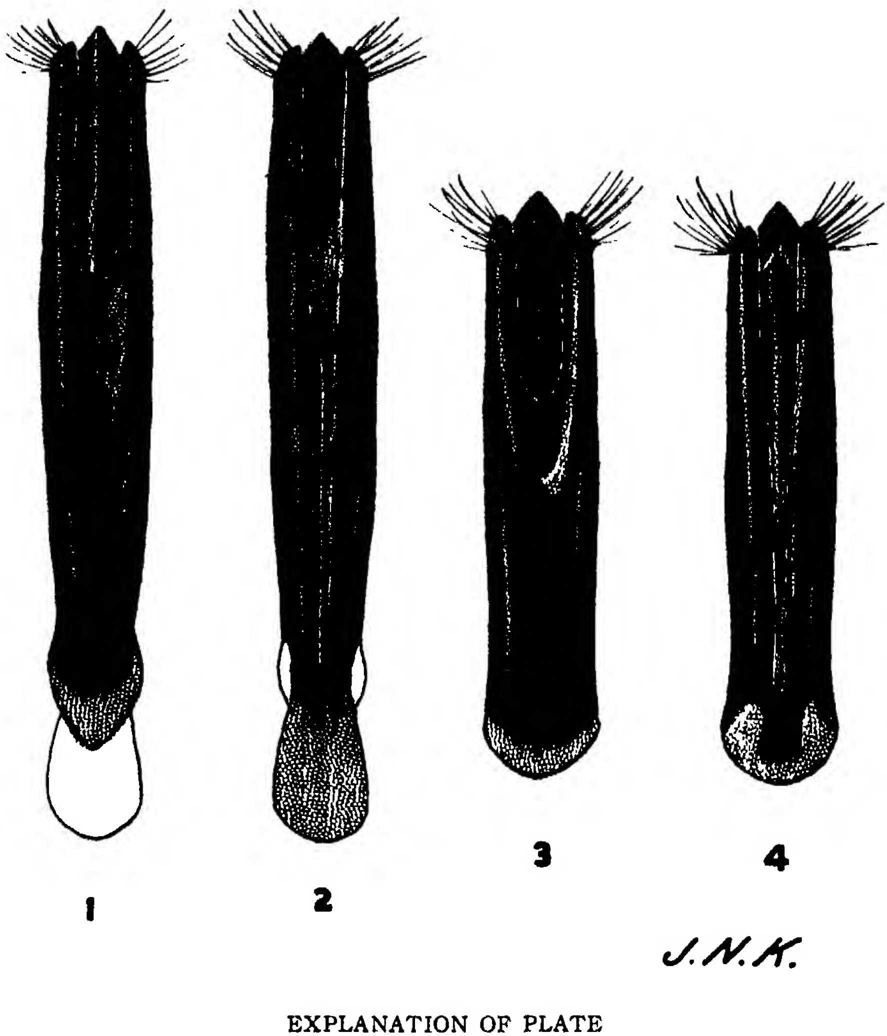
Length 4.6; width 1 2 mm.

Female.—Differs from male by not having tibiae mucronate; first two abdominal segments convex at middle.

Described from a series collected on the foliage of yellow wood (*Cladrastis lutea* (Mich.)), at Lexington, Ky., April 15, 1941, by L. H. Townsend. Holotype male, allotype and paratypes in collection of writer. Paratypes in collections of University of Kentucky and The Ohio State University

This species runs to *A. celti* Knull in Fisher's key.[1] The males lack the brilliant viridescence of many *celti* and the median ventral line of pubescence extending from prosternum to second abdominal segment of *celti* is lacking. The male genitalia are different also.

[1]W. S. Fisher, 1928. U. S. Nat. Mus. Bull. 145: 1-347.



EXPLANATION OF PLATE

Male genitalia of *Agrilus;* figures 1 and 3 represent dorsal surfaces; figures 2 and 4 are ventral views.

Figures 1 and 2, *celti* Knull; 3 and 4, *cladrastis* Knull.

A COPEPOD PARASITE OF THE CISCO FROM TROUT LAKE, WISCONSIN

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In the summer of 1944 two copepods, belonging to the genus *Salmincola*, were collected by Ralph V. Bangham from ciscos, caught in Trout Lake, Wisconsin. The body conformation and appendages are distinct from any of the described species. For this reason we suggest that our specimens are members of a hitherto undescribed species of the genus *Salmincola*.

Salmincola wisconsinensis n. sp.

Female.—The cephalothorax (Fig. 1) is strongly arched dorsally. A dorsal view of this region (Fig. 2) shows that it is greatly elongated and narrowed anterior to the bases of the second maxillae. The trunk is curved dorsally, its ventral surface flattened and containing a number of transverse grooves. Each first antenna (Fig. 3) is two-jointed, the terminal joint carries a small spine near its base and is tipped with one large and two somewhat smaller ones. The second antennae (Fig. 4) are biramose. The exopod is knob-shaped and covered with many sharp, curved spines; the endopod is two jointed, the basal joint is broad and also covered with spines, the terminal joint narrow and armed with a broad spine on the side next to the exopodite. Upon the lateral border of each of these second antennae is a small elevated surface covered with tiny, blunt projections. The mandibles (Fig. 5) are slender and each is armed with five distal teeth. Each first maxilla (Fig. 6) ends in two thumb-shaped projections, a third of these is located some distance behind the other two and curves backwards. Each of these projections carries a small spine at its tip. The very prominent maxillipedes (Fig. 7) are set well forward of the attachment arms (second maxillae). Each of these appendages is composed of three joints. Like *S. inermis*, they do not terminate in hooks, as in other species. These appendages are without palps. The second maxillae (Fig. 1) are nearly as long as the trunk. At their extremities they are joined, by a very short stalk, to an elliptical bulla. This structure is firmly anchored in the flesh and serves to attach the parasite to its host.

Only one of our specimens carries egg sacs. The eggs are arranged in five longitudinal rows.

Total length (excluding egg sacs) 6.25 mm.; length of cephalothorax 2.50 mm ; length of trunk 3.75 mm., width 1.20 mm.; length of egg sacs 10.32 mm.

Male: Unknown.

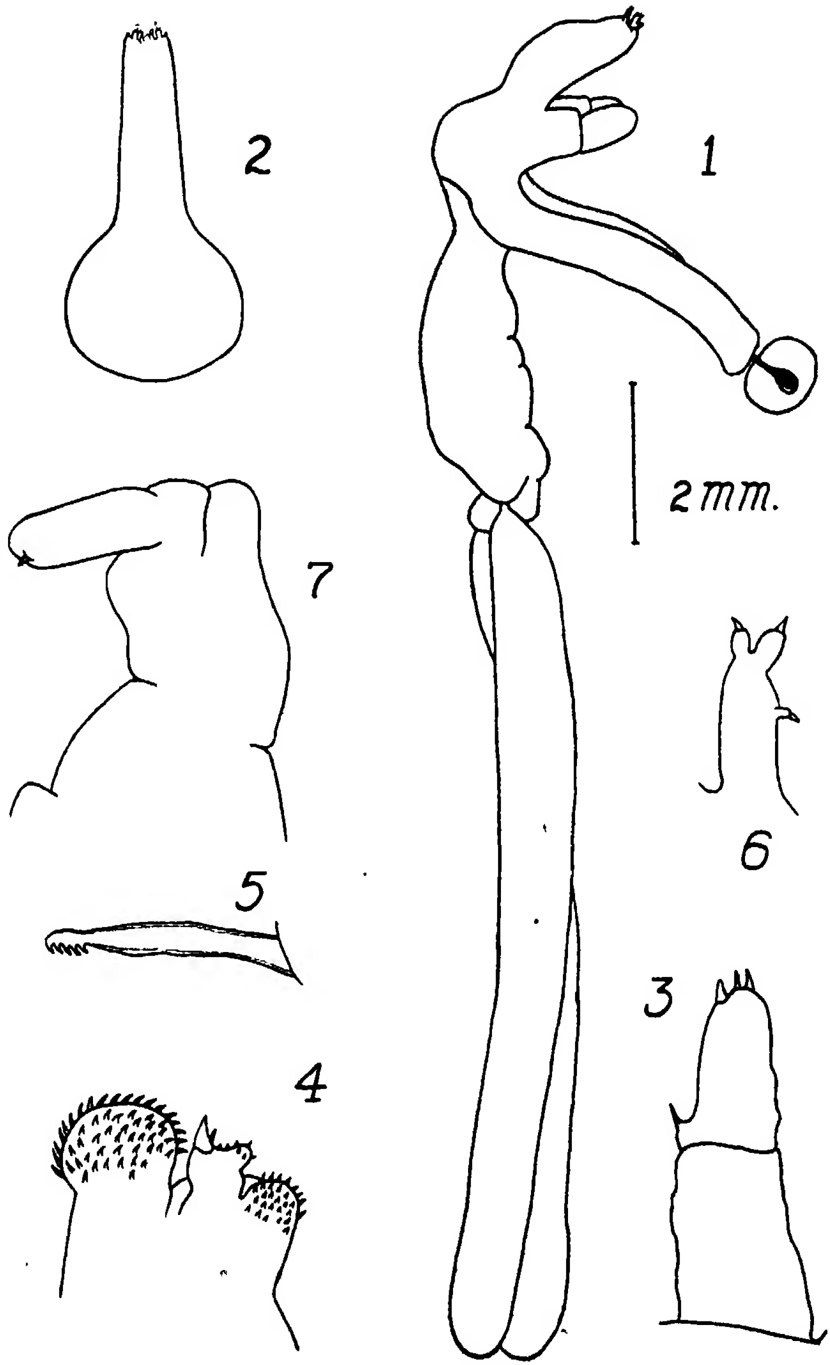
Host: *Leucicthys artedi clemensi* Koelz.

Location: Upon the surface of the body and fins.

Holotype: U. S. Nat. Mu.s Catalog No. 81553.

DISCUSSION

The affinity of the species described above is with *S. inermis* (Wilson) which is also a parasite of the cisco. However, it can be readily differentiated from Wilson's species by the marked differences in the morphology of the antennae, narrow and pointed head, and an entirely different shaped bulla. The egg sacs are not turned forward along the sides of the body as in *S. inermis* but are carried behind the trunk. The two species differ further in their choice of a location upon the host. *S. inermis* is a parasite of the gill cavity. Its umbrella-shaped bulla is held among the gill filaments, while in *S. wisconsinensis* this structure is firmly embedded upon the surface of the body and fins.



All figures drawn by the aid of a camera lucida from glycerin mounts.

Fig. 1. Lateral view of female. Fig. 2. Dorsal view of cephalothorax. Fig. 3. First antenna. Fig. 4. Second antenna. Fig. 5. Mandible. Fig. 6. First maxilla. Fig. 7. Anterior view of a maxillipede.

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Foundations of Plant Geography

In an effort to discover for himself, at least, what some of the fields of science contribute to interpretive plant geography, Professor Cain has attempted to evaluate the materials, concepts and principles of paleontology, taxonomy, evolution, genetics and cytology. The end result of the survey is a volume which he has called "Foundations of Plant Geography"—a title implying rather more than the book contains

With this observation, however, it must be immediately remarked that what Cain found out for himself is of interest to and constitutes necessary study for, both informed teachers of ecology (plant and animal) and serious advanced students alike. The factual materials in this volume are presented with a studied broadness of view and an apparent thoroughness of examination of the subjects included, and the discussions are supplemented with such an abundance of examples illustrating many concepts and principles, that few will read the book without much profit. Probably only those who are as conversant as the author with the large literature of the several fields treated (among whom the reviewer is not one) can appreciate the difficulties encountered in bringing these materials to their present state of integration, or critically review the work with respect to many of its details.

The volume is presented in five parts, the first of which consists of a brief discussion of the inter-relations of the specialized plant sciences and their importance to interpretive plant geography. Certain previously-stated principles of ecology are reviewed, examined, and illustrated with examples from the literature. Part II deals with paleoecology as a tool of the plant geographer, with a rather full discussion of its limitations, the identification of fossils, and their use in the determination of composition, dominance, living conditions, migrations and evolution of vegetation. The chapter on pollen analysis is especially clear and complete.

Dispersal, migration endemics, endemism, species senescence, discontinuous distribution, vicarious forms and areas, polytopy and polyphylesis, as well as center of origin and criteria for indicating center of origin, make up some of the topics discussed under the subject of Aerography. Part IV is an assemblage of "some of the conclusions regarding relations between evolutionary processes and their results and plant geography." Part V is a discussion of the significance of polyploidy in plant geography. The latter three sections are in part, more philosophical and illustrative examples are sometimes wanting.

The book is something more than a compilation of principles and examples. It is an attempted synthesis, based in general on the Clementsian school of thought, despite the author's renunciation of the Neo-Lamarckian views of Clements; and despite his warning that the organismal nature of vegetation is open to question, assumptions discarded by many ecologists years ago. To the fields of physiology, physiography, pedology and climatology, the author gives no special treatment, although utilizing certain principles of each. For many, these too, form a part of the foundations of plant geography. While most of the material included seems fundamental and pertinent, one curious tendency should be mentioned. It is with hope and expectation of something concrete that one approaches certain discussions such as the chapter on species senescence, only to be impressed with the futility of the whole treatment by the author's closing remark: "Other explanations can be found that have a factual basis and do not have an anthropomorphic taint." A similar impression is gained from the classification of plant propagules on the basis of their migration "adaptations." After much grandiose terminology and the listing of obvious advantages, the discussion is concluded with the statement: "On the other hand, *Carex*, with no particular means of dispersal, is distributed all over the world."

To this reviewer at least, the absence of any special treatment of microclimates, barriers and certain physiological aspects of the subject, is conspicuous, although the author does plead "lack of space" to those specialists who might decry omissions.

Throughout the volume the author has eased the reader's approach to new topics with a statement of principles, which he proceedes to examine, discuss and illustrate. About 100 maps, tables and charts emphasize and clarify certain data and concepts. A bibliography of 720 titles is included.

The diversity of the specialized sciences that make up the foundation of plant geography, their many inter-relations, their overlapping viewpoints, and the difficulty of obtaining complete field data in ecological study, are adequately indicated. With a need for a lucid presentation of the relations among these anastomosing disciplines and methods—with such a need for this pioneer job in particular—it is regrettable that so much of the terminology is unnecessary, and some pedantic. Nevertheless, it is a much-needed, useful and stimulating work—*John N. Wolfe.*

Foundations of Plant Geography, by Stanley A. Cain. Harper and Brothers, New York. 1944. $5.00.

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EPIPHYTOLOGY OF WINTER WHEAT MOSAIC

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In the spring of 1919 there appeared in Madison County, Illinois, a disease in winter wheat previously unknown in the United States. Subsequent observations revealed the same disease existing in Indiana. The disease has been referred to by such names as "take-all," "so-called-take-all," "wheat rosette," and finally "wheat mosaic," after the causal agent was proved to be a virus. Previous to the discovery of the virus nature of the malady by McKinney (17), speculation arose that the trouble was caused by the feeding of certain insects, such as the Hession fly, *Phytophaga destructor* Say, wheat straw worm *Hormolita grandis* Riley, or wheat stem maggot *Miromyza americana* Fitch, or that unfavorable soil relations were responsible (22). Wheat mosaic virus *Marmor tritici* H.[2] is of unusual interest because under natural conditions the causal agent is transmitted through the soil (16, 17, 30). When seed of a susceptible variety of winter wheat is planted in virus-infested soil in the autumn, disease symptoms do not usually appear in the plants until the following spring after winter dormancy is broken (16, 32). Furthermore, soil which previously has produced a diseased crop of wheat will retain the virus in an active state for at least six years even though no susceptible plants are present during this interval.

Because of these interesting facts the writer undertook a study of the disease to determine, if possible, how the plants became inoculated under natural field conditions. It is the purpose of the present paper to discuss some experiments on this and related problems.

GEOGRAPHIC DISTRIBUTION

In the United States wheat mosaic has now been reported from Illinois, Indiana, Kansas, Maryland, Nebraska, North Carolina and Virginia (20). Wheat mosaic has been found also in Egypt (14), Japan (29) and Russia, where it is present in almost all provinces where winter wheat is grown (33).

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[1]This study reports investigations conducted while the writer held the Elizabeth Clay Howald Scholarship, and the Muellhaupt Scholarship, Department of Botany, Ohio State University. The writer's present address is: Washington Agricultural Experiment Stations, P. O. Western Washington Experiment Station, Puyallup, Washington. Grateful acknowledgment is made to Dr. R. M. Caldwell of Purdue University, and to Dr. Benjamin Koehler of the University of Illinois, for their kind assistance in getting this study started, and to Dr. E. N. Transeau, Dr. W. G. Stover and Dr. C. C. Allison, Ohio State University, for their aid in the preparation of the manuscript. Paper from the Department of Botany, The Ohio State University, No. 471.

[2]The Latin name of the virus follows the system of nomenclature in the Handbook of Phytopathogenic Viruses (4).

Symptomatology

It is not possible in this paper to give the characteristics of each virus known to cause mosaic in wheat, but only a brief description of the disease will be given as the symptoms appear on susceptible varieties infected under field conditions in the area east of the Mississippi river. Very detailed and comprehensive descriptions of disease symptoms have been made by other investigators (6, 16, 20, 22, 23).

FIELD SYMPTOMS

Wheat mosaic is best recognized in the spring. The field is spotted with areas containing diseased plants scattered at random regardless of the soil type or condition. The plants in these areas are severely dwarfed and in some instances may be dead and lying on the surface of the ground with a few healthy appearing plants present among the diseased, thus giving an uneven appearance. The affected areas are irregular in shape, varying in size from a few feet in circumference to patches which may comprise almost the entire field. The margins of these patches are more sharply defined than those circumscribing diseased areas caused by unfavorable soil relations.

HOST SYMPTOMS

There are two types of symptoms of wheat mosaic, depending upon the variety of wheat observed. In the variety Harvest Queen, a rosetted condition develops which is characterized by excessive tillering, giving the plants an unusually dwarfed, compact appearance. Such plants are darker green than healthy ones.

In very susceptible varieties such as Purdue No. 1, Purkof and Illinois No. 2, wheat mosaic virus produces stunting without excessive tillering in addition to a mottled condition consisting of light yellow areas intermingled with the normal green (Fig. 1). These light yellow patches may be nearly circular to oblong in shape, or may take the form of large chlorotic streaks which are parallel to the leaf veins. Similar characteristics are seen on the glumes, leaves, leaf-sheaths and stems. This type of mottling is generally referred to as yellow mosaic in contrast with green mosaic which exhibits a mottle consisting of small patches or streaks of a darker green color than normally present in healthy plants. Diseased plants may survive the acute phase of the disease and produce imperfectly filled spikes which are shorter than the spikes of healthy plants.

HISTOPATHOLOGY

Microscopic examinations of stained sections of diseased plants from areas where the virus is carried in the soil reveal intracellular vacuolated bodies in the host cells (21). Similar bodies are not found in healthy plants and this fact has been used to determine whether plants are infected if no other macroscopic symptoms are visible. This criterion is not reliable in all cases, since no intracellular bodies are produced in wheat infected with the virus (18) occurring west of the Mississippi river. These vacuolated bodies may occur singly or in groups of two or three, and may be found in any position within the cytoplasm. Similar bodies have also been described from mosaic diseased wheat in Japan (28, 29) and Russia (35).

Experiments on Virus Transmission

MECHANICAL METHODS

Wheat mosaic virus is transmitted with difficulty by mechanical means from diseased to healthy susceptible wheat. It has been shown that cool temperatures are favorable for infection (20, 30), but since these conditions do not always exist in most greenhouses in the spring and summer, considerable difficulty is encountered in keeping a viable culture of the virus throughout the year. This is

especially true when one considers that the greatest source of the virus is lost after field-infected plants are matured.

In an attempt to determine the best method of inoculation, the rubbing method described by Jones (8) was compared with the needle-prick method. Carborundum powder was dusted over the plants before inoculation with infectious plant juice which was prepared by grinding parts of diseased plants in a mortar with a pestle. The mortar and pestle were previously sterilized, and a few drops of tap water were added to the inoculum to facilitate inoculation. Only young plants in a stage of rapid growth were inoculated. For the needle-prick method of inoculation a small piece of cotton was wrapped around the point of a dissecting needle allowing the point to protrude slightly through the cotton. The needle-point was kept moist by dipping the cotton in the inoculum at frequent intervals, after which the plants were pricked in several places. Inoculations were made mostly on the leaves and stems but in one experiment plants were inoculated on the roots. In this case the plants were first grown in sand then removed and the debris washed from the roots in running tap water, after which they were inoculated and transplanted in non-infested soil in clay pots. Infectious plant juice was extracted from either the roots or tops of plants and used separately as inoculum in comparative tests.

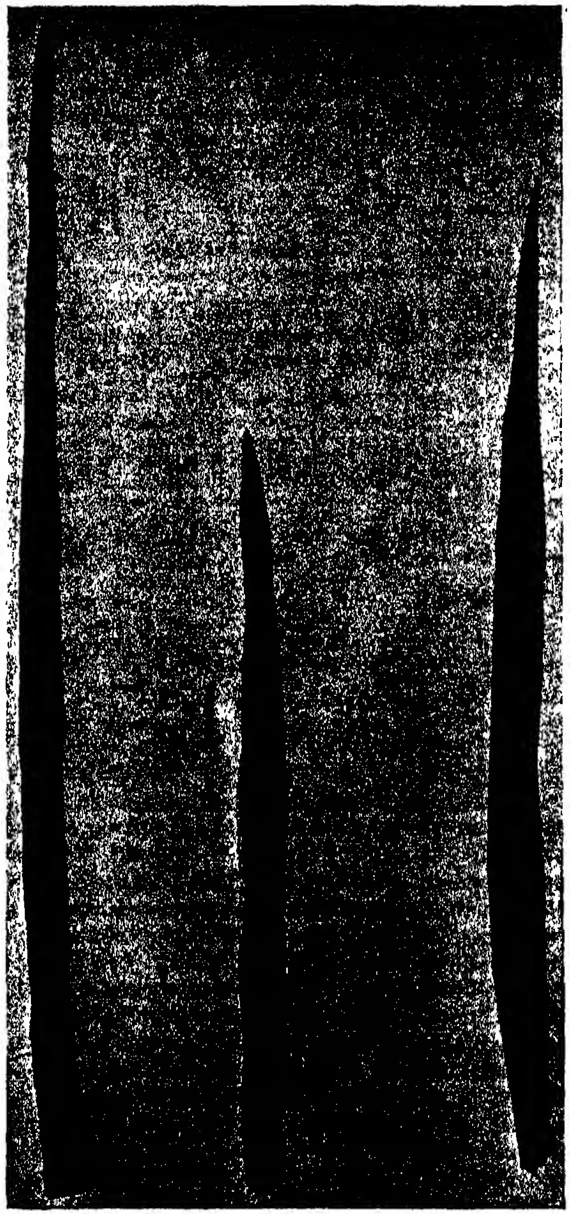

Fig. 1. Symptoms of mosaic in Purdue No. 1 wheat. The two leaves on the left show different types of mottle and are from plants which became infected with virus through the soil. The leaf on the right is healthy.

Table I summarizes the results obtained with four susceptible wheat varieties. It will be noticed from the table that there was no advantage in inoculating the roots, and no infection was obtained with

inoculum extracted from the roots of diseased plants. Neither method of inoculation was very efficient in transmitting the disease; however, these experiments were performed in late spring when the temperature was relatively high and often reached 80° F., or higher. For best results a cool uniform temperature of about 60° F. is desirable (20).

TABLE I

COMPARISON OF THE RUBBING METHOD OF INOCULATION WITH THE NEEDLE-PRICK METHOD, USING INFECTIOUS PLANT JUICE AS INOCULUM EXTRACTED FROM ROOTS OR TOPS OF DISEASED WHEAT PLANTS AND INOCULATIONS MADE IN EITHER ROOTS OR TOPS OF HEALTHY PLANTS

SUSCEPTS	PLANTS INOCULATED IN ROOTS				PLANTS INOCULATED IN LEAVES AND STEMS			
	Needle-prick Method		Rubbing Method		Needle-prick Method		Rubbing Method	
	Inoculum from Roots	Inoculum from Tops	Inoculum from Roots	Inoculum from Tops	Inoculum from Roots	Inoculum from Tops	Inoculum from Roots	Inoculum from Tops
Harvest Queen					0/63	0/62	0/38	0/38
Purdue No. 1	0/75[a]	0/75	0/75	0/75	0/73	2/56	0/47	5/43
Purkof...					0/59	7/76	0/51	3/32
Illinois No. 2					0/78	3/84	0/67	4/54

[a]The numerator indicates the number of plants diseased and the denominator the number of plants inoculated.

INFECTION OF VERNALIZED WHEAT FOLLOWING GERMINATION IN VIRUS-INFESTED SOIL

Mosaic symptoms develop in wheat in the spring following winter dormancy, but not in winter wheat planted in spring except in rare instances when unusually low temperatures prevail for a prolonged period (20). Spring wheat is also susceptible to infection when planted in the fall, but not when spring sown (18, 20). It seemed interesting to determine if wheat could be infected under artificial winter conditions produced in the laboratory and greenhouse.

The experiment was divided into two parts. In one test the seeds were sown in virus-infested soil and allowed to grow at room temperature for 18 days, after which time the plants were vernalized by subjecting them to a temperature between 2° and 3° C. for 60 days. Water was added to the soil in the low temperature chambers to keep the soil moist. After the cold treatment the plants were transplanted in either infested or non-infested soil in the greenhouse. The roots were washed in tap water to remove as much of the infested soil as possible before transplanting the plants in non-infested soil. In the second part of the experiment the seeds were germinated in sand known to be free from virus, and the wheat vernalized as previously described. Following the cold treatment the plants were transplanted in virus-infested soil.

It will be seen by referring to Table II that it is possible to produce mosaic in winter wheat by duplicating in the laboratory some of the natural conditions to which winter wheat is normally exposed. First, by allowing the plants to grow for a brief period in virus-infested soil and second, by subjecting them to a cold treatment, followed by normal growth development. Webb (30) has shown

that the wheat seedlings become infected in the fall before winter dormancy; this condition also seems to hold true under artificial laboratory conditions, although in this case the percentage of plants showing disease is much lower than under natural field conditions. This result was possibly caused by the small quantity of infested soil used in germinating the wheat, prior to the cold treatment. It has not been possible to produce mosaic in vernalized wheat germinated in sand free from virus, followed by transplanting in virus-infested soil. One thousand seedlings of the variety Purdue No. 1 were treated in this manner and not one plant showed mosaic.

TABLE II

DEVELOPMENT OF MOSAIC IN VERNALIZED WHEAT GERMINATED IN INFESTED AND NON-INFESTED SOIL IN THE LABORATORY

Suscept	Seed Germinated in Infested Soil and Plants Transplanted in:		Seed Germinated in Non-infested Sand and Plants Transplanted in:	
	Non-infested Soil	Infested Soil	Non-infested soil	Infested Soil
Purdue No. 1 ..	17/100[a]	15/100	0/100	0/1000

[a]Numerator indicates number of plants diseased, denominator the number of plants transplanted.

INSECTS

It is reported that the wheat virus occurring west of the Mississippi river is transmitted by an unidentified aphid (3), but such evidence is lacking for the virus present east of the Mississippi (18). In Russia it has been demonstrated (33) that the leaf hopper *Laevocephalus* (*Deltocephalus*) *striatus* (L.) DeLong, is a vector of the wheat virus occurring in that country, but it is not definitely known if the Russian virus is related to any of the wheat viruses in the United States. In an attempt to gain some information on the natural spread of the disease, it seemed important to study several species of local insects as vectors of the wheat mosaic virus.

Diseased plants used as a source of the virus were naturally infected by planting the seed in the fall in infested soil. The healthy test-plants, to which the insects were transferred after their viruliferous feed, were grown in clay pots and were about four inches tall. Insect cages made of celluloid were placed over the wheat and pushed into the soil to the depth of one inch. Wheat of the variety Purdue No. 1 was used exclusively in these tests.

One hundred twenty-five mature leaf hoppers, *Laevocephalus striatus*, were collected from a pasture and placed under a cage with diseased wheat. There was a high mortality among the insects. Only 23 adults remained alive after a feeding period of seven days when they were transferred to five healthy wheat plants. Seven days later the insects were removed and the plants observed for mosaic symptoms, but no disease developed up to the time when the plants were in bloom.

In another experiment the leaf hopper, *Agalia sanguinolenta* Prov., was tested. Twenty adult insects were fed on diseased plants for six days, then transferred to five healthy wheat plants where they fed for an additional 17 days. No mosaic had developed on the wheat after an observation period of 60 days.

The third experiment consisted of testing the leaf hopper, *Agalia constricta* (Van Duzee) and both macropterous and brachypterous forms of the fulgorid *Delphacodes campestris* (Van Duzee) as vectors of the virus. There were 19

insects of *A. constricta* and 60 of *D. campestris*. All insects were placed in one cage and fed on diseased wheat. After a feeding period of six days the insects were removed and separated according to species. Each group was then transferred to four healthy wheat seedlings in separate cages. Daily transfers were made to a new set of plants from April 30 to May 21, but in no case did any plants become diseased with mosaic.

One of the common aphids feeding on wheat is *Toxicoptera gramineum* Rond. Specimens of this insect were fed on diseased wheat for three days, then transferred and fed an additional six days on healthy wheat. No mosaic developed in the test plants In a second trial the same species of insects were fed on diseased plants for six days, then transferred to 50 healthy vernalized wheat seedlings with five mature aphids placed on each plant. After six days the insects were destroyed by fumigation and the plants observed for mosaic symptoms, but there was no evidence of virus transmission.

It must be concluded that the insects tested are not vectors of the virus under the conditions of these experiments.

NEMATODES

As will be seen from the following discussion, there is a certain amount of information which suggests that a soil vector of some kind is responsible for transmission of the wheat virus. It is known that the virus is not carried in the water drained from infested soil (31), and if insects hatched from eggs deposited in infested soil were responsible for transmission it could be expected that healthy, susceptible wheat grown in non-infested soil in alternate rows with plants in infested soil would also become inoculated as the insects emerged from the soil This does not happen, as only the plants in the virus-infested soil show disease Furthermore, insects emerging from the infested soil could be trapped by inserting an insect-proof cage over the soil. This the writer has attempted to do, but no insects were found in the cages. It has also been reported by McKinney (20) and confirmed by the writer that the disease develops in wheat grown in infested soil in cages which excludes all outside insects. This circumstantial evidence may suggest that the vector is not necessarily an insect, but some other organism present in the soil. Such an organism must be able to resist periods of alternate moisture and drought for a considerable length of time, as infested soil which has been air dried for at least three years produces just as severely infected plants when replanted to wheat as similar soils cultivated regularly (20).

One kind of soil-borne organism which fulfills these requirements is the nematode. It is known that species of nematodes are able to remain dormant from five to ten years (2, 27) and resume parasitism upon the advent of favorable moisture conditions. The feeding technique of plant parasitic nematodes has been studied in considerable detail by Linford (11, 12, 13). From this work it is concluded that the nematodes puncture the host cells with their stylets and injest the cell contents into their bodies by the pulsation of their esophageal bulbs. There is also evidence that saliva is injected through the stylet of the parasite into the host (11). This method of feeding is similar to that of certain insects which are important vectors of many plant viruses. From these considerations it seemed worth while to study the nematodes normally present in virus-infested soil with regard to their capacity to act as vectors of the wheat virus.

The nematodes were separated from the virus-infested soil by employing the well-known Baermann technique as described by Cort et al., (1). The apparatus used in this study is shown in Fig. 2. The nematodes were collected in watch glasses by opening the pinch cock on the funnel from six to twelve hours after the soil was flooded with water. The nemas were then drawn up in a pipette made from glass tubing, one end of which was drawn out to a fine point and either transferred directly to non-infested soil planted to a susceptible variety of wheat or

transferred to Petri plates containing cultures of the fungus Fusarium. The nemas multiplied rapidly on the fungus isolates and after two weeks time, from the date the nema cultures were started, the substratum was covered with nematodes in all stages of development from eggs to mature individuals The nemas

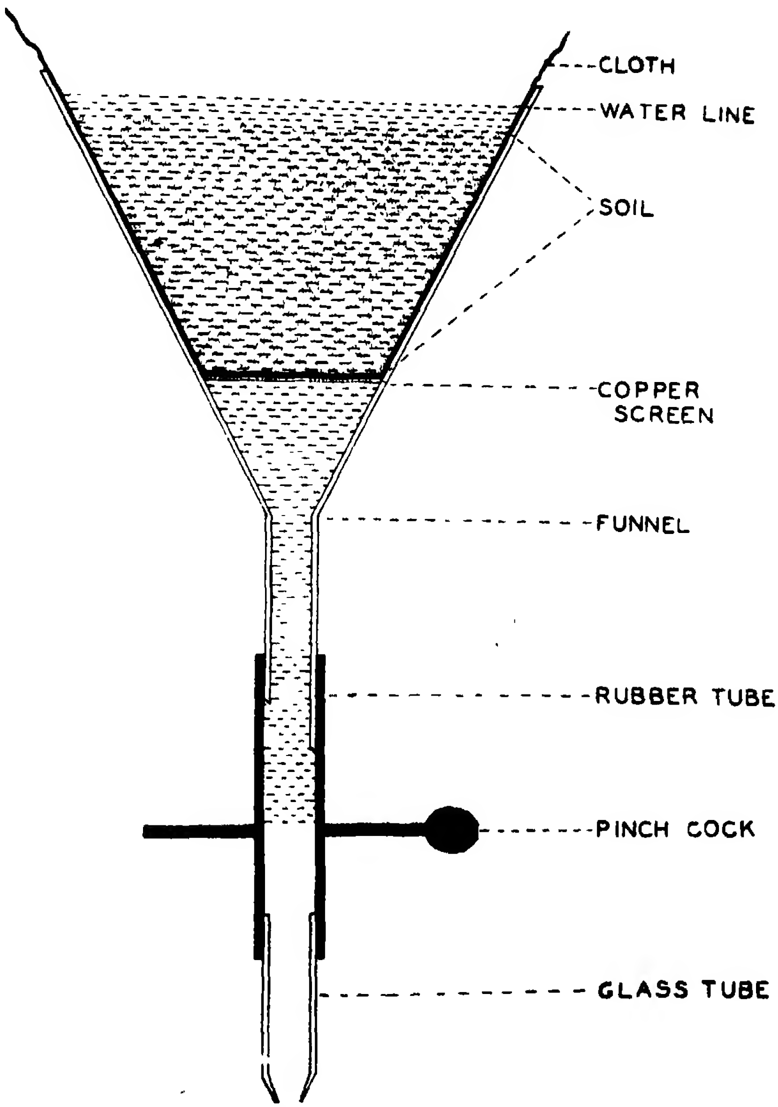

FIG. 2. Diagram of apparatus used to separate nematodes from soil.

were separated from the agar by inverting the Petri plates in water. After four hours the nemas were drained off in great abundance and transferred to non-infested soil planted to wheat. In some cases vernalized wheat was used to test for virus transmission. These trials have been repeated six times and many hundreds of plants were involved, but in no case was there evidence that the nematodes transmitted the virus.

In subsequent tests wheat seeds were surface sterilized and germinated in a water-agar medium in Petri plates to which nematodes previously separated from virus-infested soil were added. The nemas multiplied rapidly and were seen in great abundance on the roots of the wheat; however, it could not definitely be ascertained if the nemas actually fed on the roots. The plants were later transplanted in non-infested soil and observed for mosaic, but no disease developed.

From this work it seems apparent that the nematodes collected from the infested soil were not vectors of the wheat mosaic virus, but it should be pointed out that these experiments were conducted at a time when laboratory and greenhouse temperatures were high and often reached 90° F., a condition which is not conducive for the development of mosaic.

Suscept Range

Winter wheat is not a suitable experimental plant for greenhouse and laboratory work since plants must be subjected to a low temperature for a considerable period of time before they will develop normally. For this reason it was desirable to test other species of plants which might more easily become infected, and which could be used to study the virus in greater detail. All tests were conducted in a greenhouse and the plants inoculated by the rubbing method. Carborundum was dusted over the leaves before inoculation and all the test plants were young and in a stage of rapid growth. Following inoculation the plants were washed with water from a sprinkling can. Attempts were made to recover the virus from inoculated test plants which deviated in appearance from the normal by inoculating wheat with plant juice extracted from the test plants. It will be seen from Table III that only wheat in the Gramineae family was susceptible to infection. This fact is in agreement with McKinney's earlier work (16, 18) in which he found that all cereal species in the tribe Hordae were susceptible to the disease by natural infection.

Control

Although wheat mosaic does not develop in wheat grown in infested soil treated with formaldehyde (16) or in soil heated at 60° C. for ten minutes (7), the only practical method of control is by planting resistant varieties. It is beyond the scope of this paper to list all the varieties reported resistant since this information is available elsewhere (16, 23, 32). Recent work by Koehler, Bonnett, and McKinney (9) has shown that several varieties produce good yields when planted in virus-infested soil. These varieties, listed according to their order of yield over a four-year period in three different fields are as follows: Fulhard, Prairie, Nabob, Wabash, Fulcaster, Duffy, Thorne, Cooperatorka, Fulhio, Michigan Amber, Inivira, Harvest Queen 34-1, Red Wave, Shepherd, and Trumbull. Records on lodging resistance were also taken and in this regard their order of importance is: Thorne, Prairie, Fulhard, Nabob, Duffy, Fulcaster, and Wabash.

Discussion

Several viruses are reported as inducing mosaic in winter wheat in the United States. The viruses causing mosaic west of the Mississippi river differ from those east of the Mississippi in not being transmitted through the soil, and are reported transmitted by an aphid, while no insect-vector is known to transmit the eastern viruses which are carried with the soil. The two viruses may also be differentiated upon the fact that vacuolated bodies are found in the cells of plants infected with the eastern virus, while no such inclusions are produced by the western virus (18).

Two types of mosaic are described from the west (19), namely, green mosaic and yellow mosaic. The latter appears to cause the most pronounced damage, and more recently McKinney (20) isolated seven different viruses from diseased

plants grown east and west of the Mississippi river. The distinctive characteristics were based on the symptoms produced in Harvest Queen wheat grown under a definite photoperiod, host range, and whether the viruses were transmitted through the soil. Each wheat virus was designated by a numeral from one through seven. It appears to the writer that a better method would be to consider only two distinct viruses as causing wheat mosaic in the United States. Wheat mosaic

TABLE III

PLANTS TESTED FOR SUSCEPTIBILITY TO THE WHEAT MOSAIC VIRUS

	No. Plants Tested[a]
Chenopodiaceae	
**Beta vulgaris* L. (sugar beet)[b]	0/10
Compositae	
Callistephas chinensis Nees	0/10
**Helianthus annus* L	0/25
Lactuca sativa L	0/7
Fagetes erecta L	0/6
Taraxacum officinalie Weber	0/5
**Zinnia elegans* Jacq	0/20
Cucurbitaceae	
Cucumis melo L	0/7
C. sativus L.	
var. Evergreen Pickling	0/32
var. Longfellow	0/29
Cruciferae	
Brassica rapa L	0/20
Gramineae	
Oryza sativa L.	
var. Acadia	0/26
var. Blue Rose 41	0/24
var. Early Prolific	0/29
var Improved Blue Rose	0/29
var. Rexoro	0/20
Saccharum officinarum L.	0/10
Sorghum vulgare	
var. caffrorum (Thunb.) Hubb. & Rehder	0/30
var. *saccharatum* (L.) Boerb.	
*Amber.	0/38
*Atlas	0/48
Triticum aestivum L.	
var. Harvest Queen	0/76
var. Illinois No. 1	3/84
var. Purdue No. 1	5/68
var. Purkof	3/83
Zea mays L.	
*Hybrid Golden Cross Bantam	0/50
*Hybrid Indiana 616	0/50
*Hybrid Iowa 939	0/50
Leguminosae	
Medicago lupulina L	0/10
Phaseolus aureus Roxb.	
*var. Natives (so-called)	0/50
*var. Purdue	0/50
*var. Select, No 12	0/50
P. vulgaris L.	
*var. Early Golden Cluster	0/50
var Kentucky Wonder	0/14
var. Unrivalled Wax	0/16
Pisum sativum L.	
var Laxtons Progress	0/25
var Little Marvel	0/25
var Notts Excelsior	0/25
var Potlatch.	0/25
Soya max (L.) Piper	
var. Canaday	0/12
var. Chief	0/12
var D-1	0/14
var. Dunfield	0/15
var Illini	0/15
var. L 6-12	0/12
var. L 6-685	0/16
var. Mandarin	0/14
var. Mingo	0/13
var. Patoka	0/14
var. Richland	0/14
var. Scioto	0/15
var. Wisconsin 606	0/14
var Wynco	0/10
Trifolium incarnatum L	0/10
T. pratense L	0/10
T. repens L	0/10
**Vigna sinensis* (L.) Endb	0/50
Liliaceae	
Allium cepa L	0/5
Linaceae	
Linum usitatissimum L.	0/12
Solanaceae	
Capsicum frutescens L	0/3
Lycopersicon esculentum Mill	0/10
Nicotiana glutinosa L	0/10
N. rustica L	0/10
N. tabacum L	0/10
Solanum nigrum L	0/7

[a]The numerator indicates the number of plants diseased; the denominator indicates the number of plants inoculated.

[b]Plants checked with an asterisk indicates these plants showed unusual symptoms following inoculation and that attempts were made to recover virus from them by using wheat as a test plant; but no virus could be demonstrated.

virus occurring east of the Mississippi river and classified by Holmes (4) as ***Marmor tritici*** H., would retain the name wheat virus 1, according to the numerical classification. What McKinney refers to as wheat virus 2 and wheat virus 3 may be regarded as strains of wheat virus 1, and thus would be designated as wheat virus 1A and 1B, respectively. The viruses occurring west of the Mississippi may be designated as wheat virus 2, with the virus referred to by McKinney as wheat virus 4 considered the type strain Following this system further, wheat viruses 5, 6 and 7 would be regarded as wheat viruses 2A, 2B, and 2C, respectively. Until more is known about the distinctive properties, a Latin binomial is not suggested for the western virus.

The viruses inducing mosaic of wheat in Japan are probably closely related to the eastern virus in the United States (5, 28). Two types of mosaic have been described, namely, green mosaic and yellow mosaic. These are distinguished by the difference in vacuolated bodies present in the host cells of diseased plants and by differential wheat varieties susceptible to the viruses (29, 15).

In Russia there appears to be two distinct viruses capable of causing mosaic in cereals, the virus causing mosaic of oats known as "zakooklivanie" (pupation disease), and the virus of winter wheat mosaic. Both viruses are infectious for both oats and wheat as well as other plants, but certain characteristics differentiate them. The virus causing "zakooklivanie" produces vacuolated bodies and protein crystals in cells of infected plants, while the wheat virus does not induce the formation of protein crystals (24). In diseased spring crops the oat virus causes excessive tillering, while the wheat virus seems to have no such effect (34). Furthermore, different insect vectors are involved. The virus causing mosaic in oats, "zakooklivanie," is transmitted from diseased to healthy plants by ***Delphax striatella*** Fallen (26), while ***Laevocephalus*** (***Deltocephalus***) ***striatus*** (L.) De Long, is reported a vector of the wheat mosaic virus (33). Neither virus is transmitted by mechanical methods and wheat does not become infected through the soil (34), although the reports on infection through the soil by the oat virus are in conflict (10, 25).

What the relationship is between the Russian viruses and those present in the United States is not clear. If we compare soil transmission then the wheat virus in Russia is much like our western virus, and if we consider the histopathology then the Russian virus compares favorably with our eastern virus since both induce the formation of intracellular inclusions.

There is not enough information on the wheat virus occurring in Egypt to make comparisons with any of the other known cereal viruses.

From what is known about the wheat mosaic virus occurring east of the Mississippi river in the United States, the writer is constrained to believe that a soil-borne organism is the vector. This might be an insect, or some other parasite living in the soil. Although nematodes did not transmit the virus in this study, the writer feels that more work should be done on this problem. It is possible that the technique employed was inadequate to demonstrate this point. For instance, the next logical step would be to subject the plants to winter conditions after the nematodes were allowed to come in contact with the wheat plants to be inoculated.

SUMMARY

Wheat mosaic is present in Illinois, Indiana, Kansas, Maryland, Nebraska, North Carolina and Virginia. From abroad the disease has been reported in Egypt, Japan and Russia.

The virus causing the disease east of the Mississippi river is transmitted to susceptible plants through the soil and produces two distinct types of symptoms. In the variety Harvest Queen a stunted; rosetted condition is produced, with or without mottling. In other varieties such as Purdue No. 1, Purkof, and Illinois

No. 2, stunting is pronounced without excessive tillering. In these varieties a mosaic mottling is the predominant early symptom of disease. Vacuolated intracellular bodies are present in cells of diseased plants, but not in healthy.

The virus is transmitted, with difficulty, from diseased to healthy wheat plants by mechanical means. Inoculum extracted from roots of diseased plants did not produce infection in healthy plants by the rubbing method of inoculation nor by the needle-prick method. It is possible to induce the disease in wheat by artificially subjecting the plants to the normal temperatures to which winter wheat is exposed after allowing the plants to grow in virus-infested soil for 18 days.

The insects, *Laevocephalus* (*Deltocephalus*) *striatus*, *Agalia sanguinolenta*, *A. constricta*, *Delphacodes campestris*, and *Toxicoptera gramineum*, did not transmit the virus. Nematodes were also tested as vectors but the results obtained, with regards to transmission, were negative.

Several species of plants were tested for susceptibility to the disease by mechanical inoculation, but symptoms were produced only in wheat.

The only practical method of control in areas where the disease is prevalent is to grow resistant varieties. Several of these have been found to produce good yields on virus-infested land.

Two viruses may be considered as causing mosaic of winter wheat in the United States. The virus east of the Mississippi river is transmitted through the soil and induces the formation of vacuolated intracellular bodies in cells of diseased plants. The western virus is not transmitted through the soil and produces no intracellular bodies in cells of infected plants.

The virus causing mosaic in Japan is probably closely related to the eastern virus present in the United States, but the wheat virus in Russia has characteristics of both our eastern and western viruses.

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THE ALGOLOGIST AND WATER SANITATION[1]

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A potable water is a necessary adjunct to the devlopment and well being of a community. Each member expects, as a part of his communital rights, a palatable and pure water supply. If the water becomes distasteful because of sediment, peculiar flavors and odors, or if drinking it results in illness, then, and only then, will he give any consideration or thought as to the source, contaminating factors or the chemical and physical treatment which contribute to the purity of the supply

The highly technical engineering principles and problems connected with the location, construction and operation of reservoirs and purification plants are beyond the scope of this paper. Only those that pertain to the elimination of aquatic organisms which may interfere with the delivery of potable water to the consumer will be considered. Likewise, bacteriological examination is a separate study and will be ignored except in a few instances where the intimate relations between bacteria and plankton involve the algologist

To the causal observer, the work of the algologist in connection with water supplies is something new in the application of microbiology. Instead, it is a science which has been developing for nearly a century, and if I may predict, will become more and more important as the centralization of populations and industrialization increases in this or any other country.

The industrialization of an area with a subsequent increase in population demands a substantial increase in the water supply This demand is met by utilizing surface water available in lakes or rivers. Unlike the inadequate, but relatively pure well water, these surface supplies create a major problem in which algae specifically, and microorganisms in general must be combatted.

Although the study of microorganisms began with the invention of the compound microscope near the beginning of the seventeenth century, it was not until about 1850 that their importance in water supplies was recognized. After Hassall in England and Cohn on the continent first directed attention to the importance of microorganisms, the next fifty years saw important and far-reaching investigations carried on by numerous workers in this country as well as in Europe. While these investigations were of basic importance for future work, none of them resulted in a systematic examination of any particular water supply until the Massachusetts State Board of Health in 1887, established and has since maintained such a survey. Numerous cities soon followed its example. However, satisfactory methods to control microorganisms were not known until 1905 when Moore and Kellerman proposed the use of copper sulfate for the elimination of algae. This was the beginning of the modern period of algal control in water supplies.

All natural water sources such as lakes, rivers, streams and ponds, and in some cases, artificial wells which are maintained by underground streams, contain plankton. The name "plankton" is applied in water supply work to all microscopic or near-microscopic organisms, both plant and animal, which maintain a free-floating existence in bodies of open water. Although plant and animal plankton are involved in water sanitation, the microscopic plants or algae, are of

[1]Papers from the Dept. of Botany, The Ohio State University, No. 482. The data pertaining to the Columbus, Ohio, reservoirs were obtained during yearly surveys directed by Mr. Charles P. Hoover, Chief Chemist of the Columbus City Division of Water.

primary importance because they alone can manufacture and contriubte to the food supply of the animal plankton. Elimination of the algae is therefore the first step in the control of the animals.

The identification and the determination of the number of algae present is the initial problem in the treatment of any reservoir. The investigator must be able to identify all common plankton algae, to the species if possible, under relatively low magnification. This is imperative because the counting chambers used do not permit the use of high magnifications. Only trained algologists who are thoroughly familiar with range in forms and structures of the various species encountered can satisfactorily undertake this part of the work.

A great many species of algae may be present in a reservoir but more than likely a few species will be found in sufficient abundance to affect the water supply. Ususally there are great variations in the number of individuals in these species. As all species are not equally obnoxious, quantitative rather than qualitative studies are necessary. It is not the intention here to enumerate all the plankton algae which may be encountered. Such information, if desired, may be readily secured from standard manuals of the algae. The following list does however, present a few of the important flavor and odor producing genera, or which, because of shape and structure may prevent proper filtration and necessitate frequent cleaning or "backwashing" of the filter beds.

BLUE GREEN ALGAE	GREEN ALGAE	YELLOW GREEN ALGAE AND DINOFLAGELLATES	DIATOMS
Anabaena	*Pandorina*	*Synura*	*Asterionella*
Microcystis	*Volvox*	*Uroglena*	*Synedra*
Aphanizomenon	*Tetraspora*	*Dinobryon*	*Fragillaria*
Rivularia	*Spirogyra*	*Ceratium*	*Tabellaria*

The diatom genera *Synedra*, *Fragillaria*, and *Asterionella* cause much of the filtration trouble, although mats of *Spirogyra* or other filamentous algae settling on the filters may result in similar difficulties. These, as well as a number of other genera including those listed above may cause unpleasant odors or flavors. Some algae, for example the species of *Synura* which has the odor of cucumbers, may be identified on the basis of odor alone. Other odors or flavors produced by algae may be described as fishy, grassy, moldy, pig pen, and aromatic such as geranium, violet, or nasturtium. Other than *Synura* which is extremely disagreeable, the blue green algae probably account for a large proportion of bad tasting water because of their wide occurrence and the great rapidity with which they grow and multiply. In all instances the odor is presumably due to oils produced within the cells of the alga and liberated into the water upon their death and decomposition. This explains the sharp increase in the odor intensity of water for a few days following the application of an algicide. Results of bacteriological studies during this period show a great increase in the number of bacteria which is inversely correlated with the decrease of the algae. The intensity of the odors are stated in terms of "The Threshold Odor Number," a figure which represents the dilution of the sample that is required to reduce the odor to a point where it is just detectable. An odor free water is used to dilute the sample. With the realization that Synura oil can be recognized in concentrations as low as one part in twenty million parts of water it becomes apparent that the algae must be eliminated at the source rather than at the pumping station.

The value of the data obtained will depend largely upon the careful selection of stations at which periodic collections are made. These stations should include

areas of greatest plankton concentration as well as those that will yield data concerning the effect of tributary streams entering the reservoir. The extent to which sewage or industrial contamination, algal growth, and commercial or pleasure navigation may be highly important.

Samples may be obtained by one or more of several methods. If a complete tabulation of all organisms is desired, a known quantity of the water may be centrifuged. Another excellent procedure is that known as the Sedgwick-Rafter Method. By this method the organisms are removed from the sample by means of a layer of fine sand supported on bolting silk, then washed from the sand by a measured quantity of distilled water. The objections to this method are the amount of equipment necessary, the time necessary for filtration, and a possible loss of organisms which stick to the sand. If the results justify the means, and extreme accuracy may be sacrificed, then the net method may be used. In this procedure a known amount of water is passed through a net of silk bolting cloth. These nets come in various size mesh but the No. 20 mesh is relatively satisfactory. Although part or all of the small plankton may pass through the net, most of the objectionable species of algae are retained. If the net is handled in the same manner each time a collection is made, and the same amount of water is passed through at each collection, the final result is a figure that represents the relative abundance of the important species of algae present. The writer has used this method with satisfactory results during the past several summers in plankton surveys for the Columbus City Division of Water, Columbus, Ohio.

The resultant filtrate from the net may be made up to any desired volume for easy and rapid computing. In the Columbus survey, 25 gallons of river water are filtered through the net and the resultant sample made up to 50 cc. with a standard preservative. At this concentration, one cc. of sample is equal to one-half gallon of river water. Preservation of the sample is necessary if they are to be kept for even a few hours. If not preserved, decomposition and the use of the algae as food by the zooplankton will render the sample useless. A word of caution here is advisable. Colonies of *Synura*, *Uroglenopsis* and *Aphanizomenon* disintegrate upon preservation. Samples containing these genera should be worked while still living, or immediately after fixation. The latter is better with motile algae as it is almost impossible to count the living organisms. The population is determined by transferring one cc. of the sample to a standard counting chamber holding one cc. and which is one mm. deep. By using a Whipple disc which has been calibrated to give a field of one sq. mm., the number of each species in one cu. mm. of sample is determined. At least ten such "counts" should be made, and for greater accuracy up to twenty-five should be made. The average of these counts multiplied by one thousand will give the average number of each organim in one cc. of the sample. If this one cc. of sample represents one-half gallon of water then the average number of each organism per gallon of water in the reservoir is easily computed by doubling the number in the sample. If it is desirable to have the final results expressed in terms of the metric system one may work with liters instead of gallons. However, if the work is part of an organized program of a City Water Filtration Department, it is well to keep results in the terms ordinarily used by other workers at the station.

Counts should be made at intervals of not more than one week. If the results show a rapid increase of one or more objectionable species, steps toward their elimination should be taken immediately. If development is allowed to continue, the resultant "Water bloom" will be so intense that treatment will result in extremely disagreeable odors. If the bloom is checked early in its development, it will be less difficult to control, and the after effects are far less evident to the consumer. Control should also be initiated if there is a general and steady increase

of all species because the enormous volume of decomposing organic material will produce some disagreeable odors or flavors.

The most satisfactory method for the control of algae in reservoirs, lakes, ponds or pools is that proposed by Moore and Kellerman in 1905. The control, as previously stated in this paper, is accomplished through the use of copper sulfate. This compound as an algicide is cheap, effective, easily applied, and harmless to human beings in the concentrations found effective. Any objections to its use in drinking water are unfounded. Copper is normally present in the human body and many of our foods contain greater quantities of the metal than is found in the water following treatment When $CuSO_4$ is applied to the water in a reservoir much of it changes to insoluble compounds so that the water which reaches the consumer has an extremely low concentration of soluble copper compounds.

The following list of algae with the concentrations of $CuSO_4$ effective in their elimination should allay fears in this regard. In each instance the figure following the algal name represents the number of parts of water to one part of $CuSO_4$.

Aphanizomenon	5,000,000	*Pandorina*	100,000
Anabaena circinalis	10,000,000	*Volvox.*	4,000,000
Asterionella	8,000,000	*Synura...*	3,000,000
Synedra	600,000	*Spirogyra.*	25,000,000

The above list represents only a portion of an extended list published by Moore and Kellerman in the U S Department of Agriculture, Bureau of Plant Industry, Bulletin No. 76, 1905. These concentrations, based on water of average hardness and having a temperature of 59° F., will vary slightly in water at other temperatures and degrees of hardness. The amount of $CuSO_4$ needed is determined on the basis of the volume of the reservoir and the kind of algae present. It may then be applied by towing a gunny sack of the crystals behind a slow moving motor boat or row boat The process may be expedited by the installation of a pump and mixing unit in a relatively fast motor boat. Powdered $CuSO_4$ is mixed with water pumped from the reservoir and the resultant solution sprayed from the rear of the boat. The advantage of this method is a more uniform and better application with less waste of material and time.

There is no possible way to satisfactorily predict the intervals between applications. Hardness of the water, temperature, and organic content, as well as the reappearance of resistant forms of algae all combine to make such predictions of little value Satisfactory results depend upon regular periodic surveys by the algologist. In some reservoirs it will be found that treatment is required only during the early spring and late summer or autumn months, and may be correlated with the usual maxima of diatoms at those periods. In others, the development of blue green algae will necessitate continuous treatment throughout the summer. In the Columbus, Ohio, reservoirs, spring treatment is seldom necessary because of high turbidity.

If this turbidity is continuous or nearly continuous during the summer, treatment is either eliminated or reduced to a minimum. An excellent example of this occurred in the Griggs reservoir at Columbus during the summer of 1943. Figure 1 shows graphically that five maxima, based on total organisms present, occurred between July 1 and November 3.

In the first four instances, as the organisms approached proportions indicating the desirability of applying $CuSO_4$, severe storms occurred over the water shed. The resulting turbidity and consequent decrease in light available to the algae reduced photosynthesis. This in turn sharply curtailed the growth and number of algae. The fifth maximum which occurred about October 13, disappeared shortly because of an extended period of cloudy weather, some precipitation, and a sharp drop in temperature. Such turbidity provides an excellent natural control for

the algae. This method has met with success in ponds and shallow lakes where turbidity can be created by artificial means.

In any algal elimination program there is one precautionary measure of which those in charge must be cognizant. If the body of water is open to fishing, it must be remembered that $CuSO_4$ is toxic to fish as well as to algae. Although little work has been done regarding the tolerance of fish in this respect, it is definitely known that the concentrations of copper which they can withstand vary almost as widely as they do in the algae. Likewise, the tolerance to the copper depends to a great extent upon the carbonates present, the temperature, and the amount of organic material. Some of the more common varieties of fish and the concen-

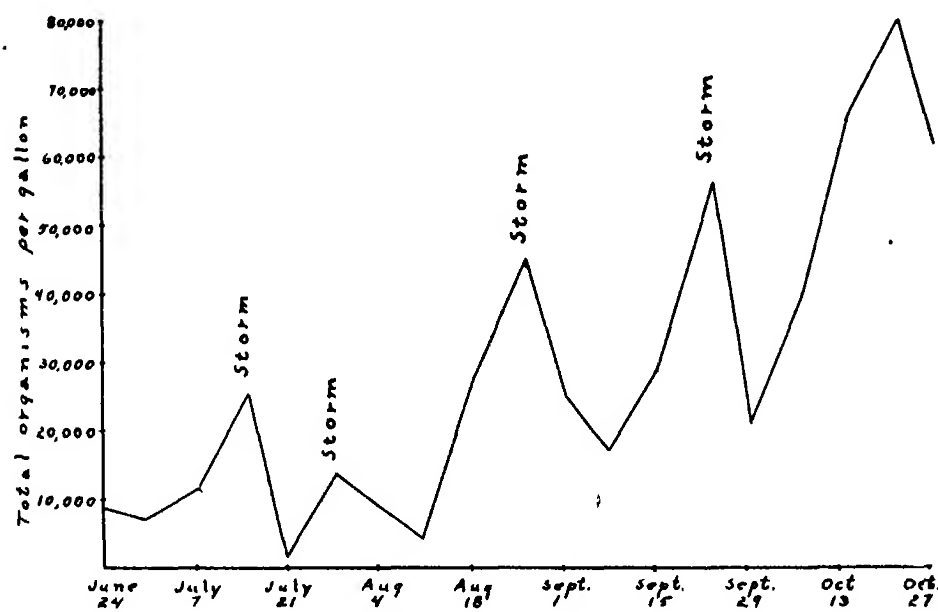

Fig 1 Graph showing the maxima of total organisms in the Griggs Reservoir of the Columbus City Water Supply, Columbus, Ohio, during the summer of 1943

trations of $CuSO_4$ which may safely used are given below These figures are the result of the investigations of Moore and Kellerman. The figures represent the number of parts of water used to one part of $CuSO_4$.

Black Bass	500,000	Catfish	2,500,000
Sunfish	750,000	Carp	3,000,000
Perch	1,500,000	Trout	7,000,000
Goldfish	2,000,000		

Consistent and favorable results during the past forty years prove the efficiency of $CuSO_4$ as an algicide. The tabulation of a few results obtained through its use in the Columbus, Ohio, reservoirs will exemplify this efficiency

On September 21, 1942, the plankton counts at three stations in the Griggs Reservoir of the Columbus water supply showed a decided increase in the number of organisms present. In order to prevent the development of a late autumn bloom, $CuSO_4$ was applied at the rate of nine pounds per acre. On October 5, counts were again made which showed that the development had been checked

and the number of organisms considerably reduced. During this period weather conditions were relatively constant. A tabulation of the results is given below:

Station No.	Total Organisms per Gal. before Application of $CuSO_4$	Total Organisms per Gal. after Application of $CuSO_4$
1	12,240	1,440
2	9,360	2,400
3	6,480	1,200

Another excellent example of algal control resulted from the investigations of Professor W. L. Huff, who, in 1915, was employed by the city of St. Paul to study the microorganisms of Vadnais Lake, St. Paul, Minnesota. The effects of $CuSO_4$ on the microorganisms are shown graphically in Figure 2.

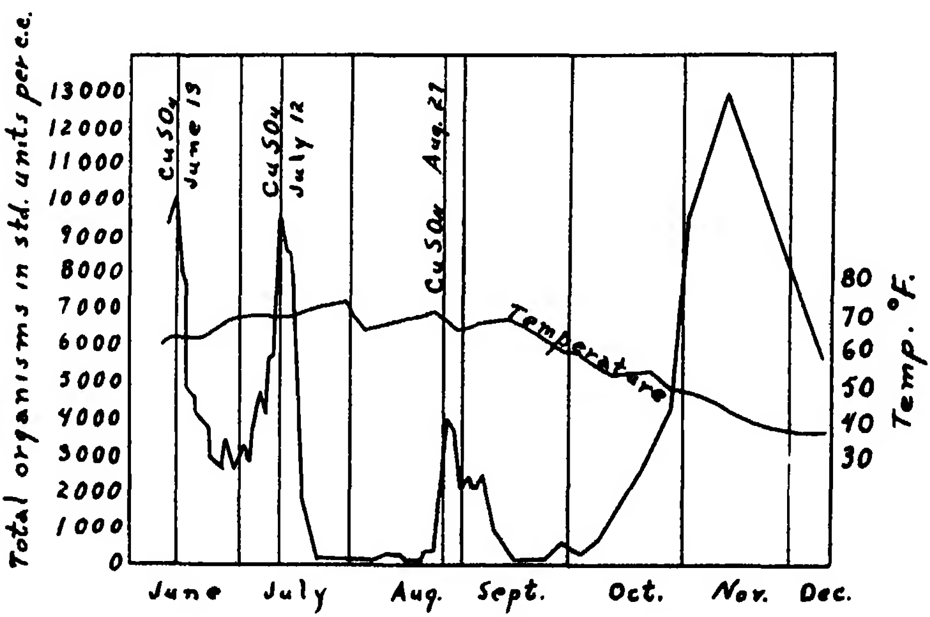

Fig. 2. Results of copper sulfate treatment of Vadnais Lake, St. Paul, Minn., 1915. After Huff.

Results, such as the above are representative and indicate the success of an algal control program.

The intention of the writer throughout the foregoing discussion has been to acquaint the reader with problems connected with algal control in water sanitation. Although most of the methods have been published, it is felt that a summary of the local work will help the average consumer to appreciate the efforts being made to supply him with the best possible water. Also that in the future the problems of water supply control as purity, freedom from odors, flavors, hardness and many other qualities will increase rather than diminish. The solution of these problems will depend upon adequately trained aquatic biologists, bacteriologists and chemists working in co-operation.

ELEVEN NEW LEAFHOPPERS WITH NOTES ON OTHERS (HOMOPTERA: CICADELLIDAE)

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Alconeura socorroana n. sp.

Near *A. planata* Ball and DeLong, but male with processes at apex of aedeagus shaft. Slender, vertex evenly rounded, pronotum one-third longer than vertex, second apical cell pedunculate.

Evenly olive green with pale areas as follows: Anterior margin of vertex and median narrow line; lateral and anterior margins of pronotum, also short antero-median line; scutellum, median line in basal half and lateral line either side defining inner margins of lateral angles, basal area and some irregular spots along claval vein, apical area along veins and two indefinite spots in outer apical cell Disc of pronotum and inner base of scutellum darker; round black spot in fourth apical cell one-fourth distance from base near vein, and small area at base of cell darkened. Below, fumose but for anterior margin of head.

Inner male genitalia.—Aedeagus in lateral view three times as long as basal width discounting length of pair of apical dorsal retrorse processes which curve back toward shaft opening and are one-third length of shaft: three ventral basal processes parallel with shaft, one median ventral and two lateral, extending a little beyond shaft opening, lateral processes longer. Pygofer process heavy, in dorsal view as long as aedeagus, curved gently inward and tapered to apex.

Female.—Last ventral segment three times as long at middle as broad, narrowed on apical third, produced in a rounded lobe, pygofer narrow with line of six white spines either side of ovipositor, evenly distributed; ovipositor exceeding pygofer.

Length: 2.5 mm.

Male holotype, two male paratypes and allotype, Socorro Co., N. M., July 10, 1940, D. J. & J. N. Knull; three teneral specimens, Tucson, Ariz., May 13, 1941, D. J. & J. N. Knull.

Typhlocyba sciotoensis n. sp.

Resembling *T. luculla* Medler externally and near *T. piscator* McA. in type of inner male genitalia which are very complex.

Chalky white with yellowish tinge on head and pronotum, a darkened scutellum, darker in median basal area, and pronounced dark band over white crossveins, extending farther anteriorly than posteriorly. Eyes dark, vertex with thin impressed median longitudinal line reaching almost to apex, a round spot either side near apex; some subcutaneous darkening of pronotal disc and area adjacent to scutellum. A dark round spot at inner posterior end of M_4, an intensely darkened streak below outer crossvein and another on outer R_3.

Male genitalia.—Outer clasper broad basally, contracted below middle; pygofer truncate on outer margin, exceeded by claspers and aedeagal processes, style with sharp projecting heel and sharply pointed, up-turned toe. Aedeagus in ventral view, a pair of narrow ventral processes arises at base and extends ventrad to shaft for two-thirds its length, arms separated at base by three times width of shaft and parallel entire length. Apex of shaft broadened slightly and curved decidedly ventrad, a pair of incurving processes before apex, a lateral branched pair behind them, and a third longer pair curved sharply ventrad toward apex arises still further back. In lateral view, aedeagus shaft curved narrowing from broad base to complex apex, forming an incomplete semicircle. Shaft somewhat swollen at juncture of processes. Female segment roundly produced; ovipositor dark.

Length: 3 mm.

Male holotype and paratype, Scioto Co., Ohio, June 10 and 17, 1944, D. J. & J. N. Knull, and allotype, Delaware Co., Ohio, July 3, 1942, D. J. & J. N. Knull.

Typhlocyba foliosa n. sp.

Near *T. piscator* McA., from which it differs chiefly in having a much paler dorsum.

Head, pronotum and scutellum ivory, eyes pale, tegmina whitish hyaline, sometimes faintly tinged with yellow; areas between sectors anterior to crossveins, slightly dark clouded, distinct black marks on veins at outer edge of R_1 and on claval margin at apex of vein M_4. Below pale, ovipositor dark and dorsal abdominal segments sometimes narrowly black margined.

Male genitalia.—Similar to those of preceding and also to those of *T. piscator* McA. in general form. In this species, however, aedeagus has ventral basal processes distinctly curved, S-curved in lateral view, and shaft is swollen at base and apex. Two pairs of apical processes, apical shorter, almost complete a circle in lateral view. In ventral view apical processes appear straight and pointed, the others are enlarged leaf-like and curved forward.

Length: 3 mm.

Male holotype and paratypes, four male and one female, Shawnee Forest, Scioto Co., Ohio, June 9, 1943, D. J. & J. N. Knull; allotype and two female paratypes, June 17, 1944; four male paratypes, June 10, 1944; paratypes from other localities: two males, Hocking Co., Ohio, September 16, 1943; one male, Delaware Co., Ohio, June 27, 1943; one female, Lucas Co., Ohio, June 30, 1943; and one male paratype, Great Smoky Mt. National Park, Tenn., June 21, 1942 (this specimen decidedly yellow-tinged), all collected by D. J. & J. N. Knull. Six paratypes in collection of The Ohio State University.

Erythroneura stupkaorum n. sp.

In the maculata group near *E. triangulata* Beamer, but with a distinctly different style in inner male genitalia

General ground color creamy white, yellowish semihyaline elytra marked with orange. Vertex with three basal pale spots, lateral round and median elongate, surrounded by continuous orange bands; pronotum with median rectangular spot not reaching margins, with translucent anterior lateral arms forming rough Y, spot back of each eye, eyes tan; apex of scutellum orange, remainder pale; clavi with three indistinct spots, not joined, coria with similar spots, one on costa before humeral angle, three around plaque and one near apex of clavus; crossveins faintly reddened, small black spot in base of cell M_4.

Male genitalia.—Pygofer hook single, distinctly S-curved, exceeding pygofer by one-half its length, noticeably thickened on middle half, inner edge of thickened portion serrate. Style with large foot, heel scarcely projecting, almost a right angle, posterior point longer than base of foot, slender, curved very slightly out, sharp. Aedeagus short, heavy, bluntly square, the knob-like apex with lateral wing-like projection, in lateral view narrow, roughened, straight.

Length: 3.25 mm.

Male holotype, allotype and paratypes, Smoky Mt. National Park, Tenn., collected in June by D. J. & J. N. Knull. Three paratypes in collection of The Ohio State University.

Named for Mr. Arthur Stupka, Park Naturalist, and his family.

Erythroneura trautmanae n. sp.

In the maculata group, resembling *E. knighti* Beamer, but with unique pygofer hook.

Creamy white on anterior parts and below, elytra yellowish semihyaline, with orange and

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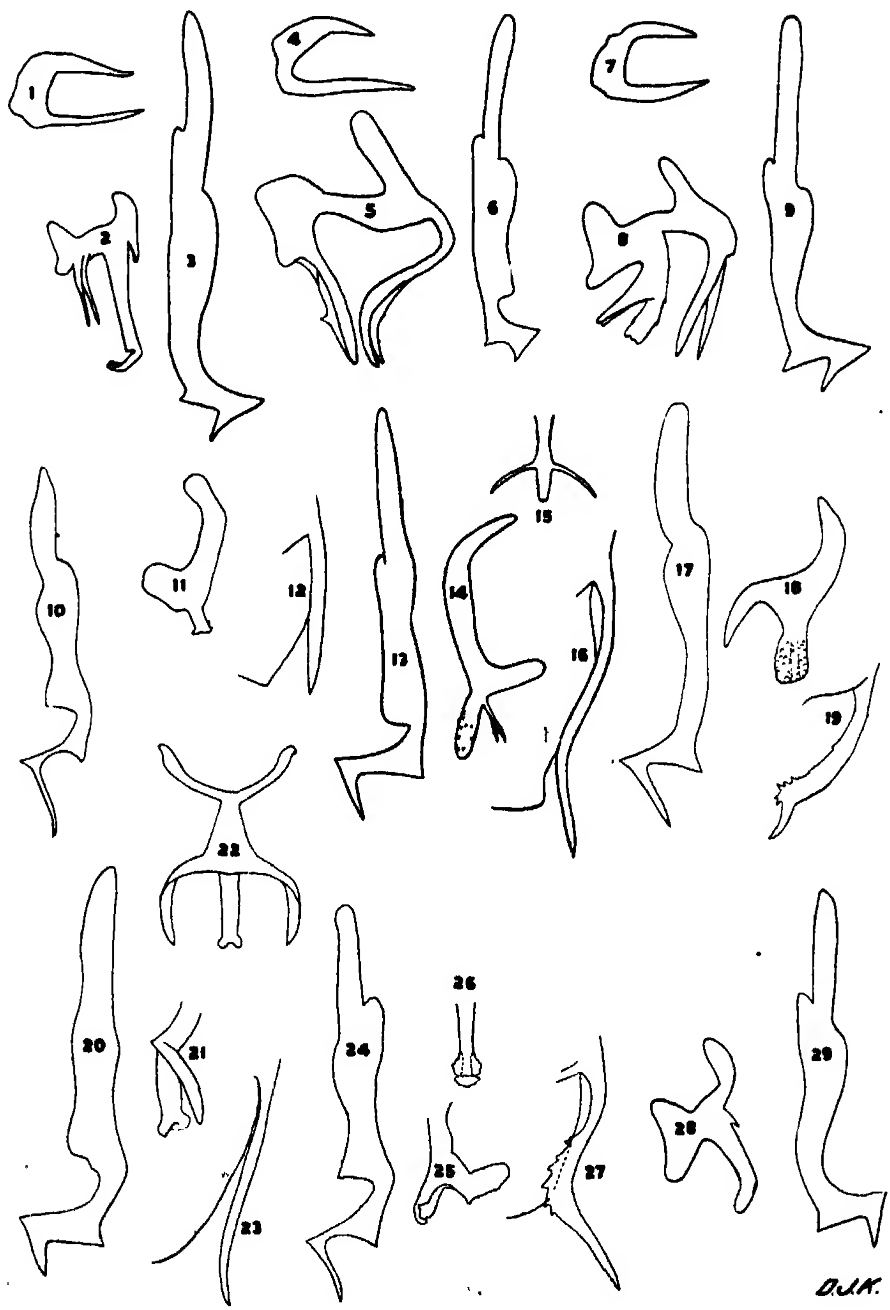
EXPLANATION OF PLATE I

Erythroneura kennedyi n. sp. Figs. 1, pygofer hook; 2, lateral view aedeagus; 3, style.
Erythroneura noncincta Johnson. Figs. 4, pygofer hook; 5, lateral view aedeagus; 6, style.
Erythroneura vagabunda n. sp. Figs. 7, pygofer hook; 8, lateral view aedeagus; 9, style.
Erythroneura corylorubra n. sp. Figs. 10, style; 11, lateral view aedeagus; 12, pygofer hook.
Erythroneura geronimoi n. sp. Figs. 13, style; 14, lateral view aedeagus; 15, ventral view aedeagus; 16, pygofer hook.
Erythroneura trautmanae n. sp. Figs. 17, style; 18, lateral view aedeagus; 19, pygofer hook.
Erythroneura paraesculi n. sp. Figs. 20, style; 21, lateral view aedeagus; 22, ventral view aedeagus; 23, pygofer hook.
Erythroneura stupkaorum n. sp. Figs. 24, style; 25, lateral view aedeagus; 26, ventral view aedeagus; 27, pygofer hook.
Erythroneura ohioensis n. sp. Figs. 28, lateral view aedeagus; 29, style.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apically orange-red markings. Vertex with three basal white spots, median longer, bordered by even band, pronotum with median Y-shaped mark, the arms reaching anterior margin, a large angular spot behind eye reaching halfway to posterior margin, scutellum with basal angles and apex orange; elytral markings diffuse and indistinct, in some specimens reddened on apical half. Clavi with basal anchor-shaped spot and one at apex; coria with indefinite area at base, spot opposite hyaline area of clavus and one at apex of clavus, plaque area irregularly colored. Cross-veins and longitudinal veins brightly reddened, giving the elytral apices a reddish hue, small round black spot in base of cell M_4.

Inner male genitalia.—Pygofer hook single, point extending very slightly beyond pygofer, broad and parallel-sided to apical half where it is toothed on inner margin, turned sharply out near apex, then from turn narrowed abruptly to sharp spine-like apex. Style with rather small foot; heel large; base curved; anterior point projecting sharply laterad, posterior point longer than base of foot, straight, tapering to apex; aedeagus long, narrow and straight in ventral view; broad in lateral view.

Length: 2.9 mm.

Named for Dr. Mary Auten Trautman who collected the type series. Male holotype, July 17, allotype, July 18, and paratypes July 18 and 21, Hartwick St. Park, Mich.; paratype, Great Smoky Mt. National Park, Tenn., June 14, 1942, D. J. & J. N. Knull.

Erythroneura paraesculi n. sp.

A large brightly colored species of the maculata group near *E. aesculi* Beamer in external appearance.

Ground color creamy white on anterior parts and below, yellowish white on semihyaline elytra. Eyes gray, sometimes brown, markings of vertex, pronotum and scutellum pale orange and of usual maculata group type. A triangle of dark red occupies basal third of clavus based on claval vein and with apex at scutellar apex; another red vitta forms a heavy irregular U-shaped mark on elytra together, with its base including area just above apices of clavi and arms extending on coria not to costal margin; a small black dot anterior to costal plaque and outer crossvein reddened, an elongate black spot in base of inner apical cell. Elytra markings may be faint in specimens taken in June.

Male genitalia.—The unusual form of aedeagus readily separates this species. Style, posterior point almost half as long as base, sharply pointed and curved in; anterior point sharp, less than a right angle, slightly projecting; heel sharp, scarcely projecting, base thick. Pygofer hook long, slender, straight, tapering to fine point exceeding pygofer by one-sixth its length, curved gently ventrad. Aedeagus in lateral view with broad shaft bulging at middle, a ventral spine at middle and apex roughened with ventral and dorsal projections, heavy basal lateral processes as long as shaft extend laterad and ventro-caudad. In ventral view shaft narrow, broadened at apex where it is roughened and has lateral wing-like projections; heavy lateral processes extend straight out from base for half their length, then, broadened a little, extend down and forward, the whole forming a large m-shaped figure.

Female.—Last ventral segment long with median third well produced in a narrow lobe.

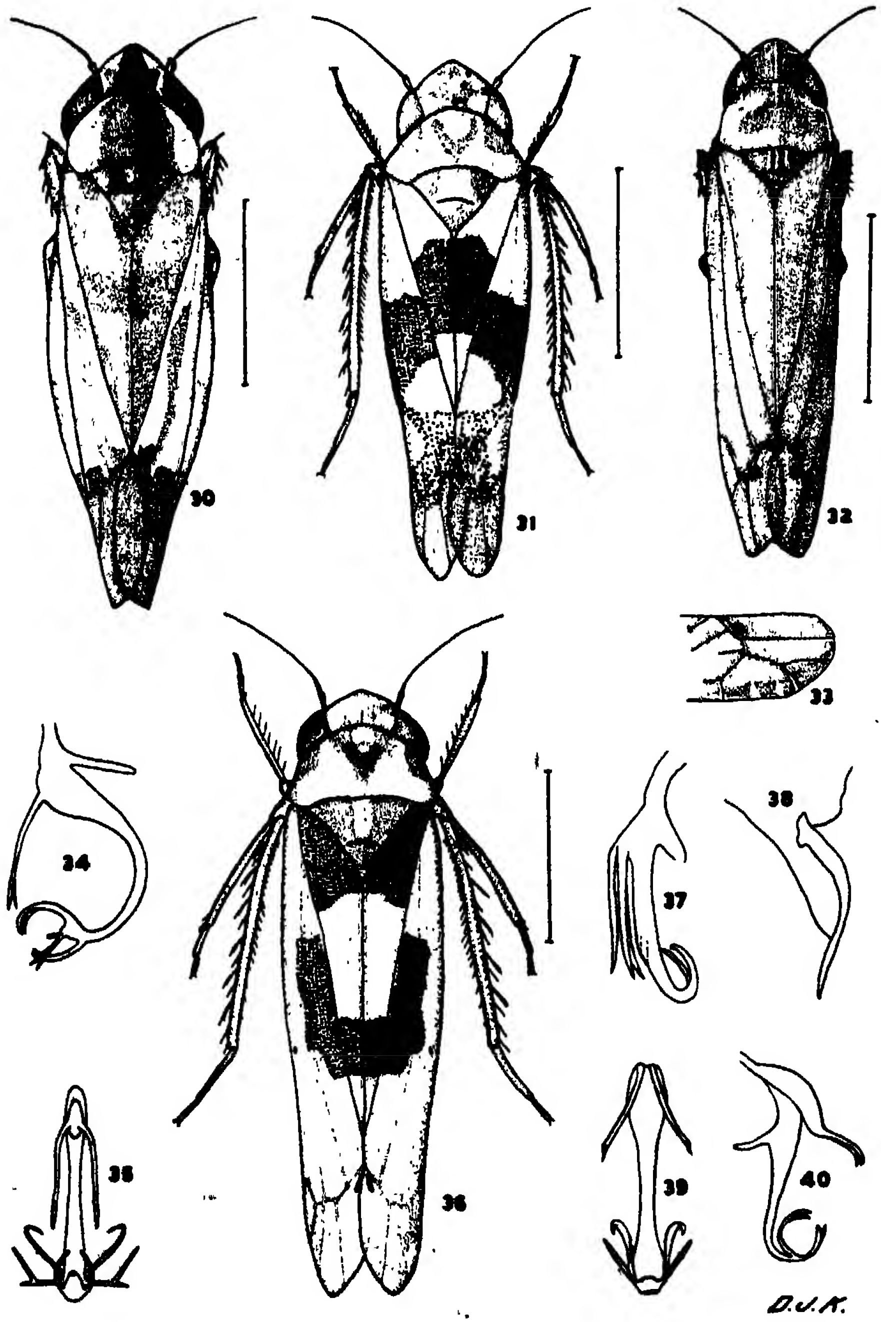
Length: 3.5 mm.

Male holotype, allotype and paratypes, Indian Gap, Smoky Mt. National Park, Tenn., June, 1942, D. J. & J. N. Knull, from *Aesculus*, and paratypes same locality, September 3, 1939, Mary Auten. Six paratypes in collection of The Ohio State University.

EXPLANATION OF PLATE II

(Line = 1 mm.)

Fig. 30, *Erythroneura ohioensis* n. sp.
Fig. 31, *Erythroneura corylorubra* n. sp.
Alconeura socorroana n. sp. Figs. 32, dorsal view; 33, tip of elytron.
Typhlocyba sciotoensis n. sp. Figs. 34, lateral view aedeagus; 35, ventral view aedeagus.
Fig. 36, *Erythroneura paraesculi* n. sp.
Alconeura socorroana n. sp. Figs. 37, lateral view aedeagus; 38, pygofer hook.
Typhlocyba foliosa n. sp. Figs. 39, ventral view aedeagus; 40, lateral view aedeagus.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Erythroneura corylorubra n. sp.

This rare, minute, brightly ornamented species has been taken on *Corylus*, and belongs in the maculata group.

Head roundly produced one-half its length beyond eyes, eyes black, markings of head, pronotum and scutellum typical for this group, faint, yellow translucent and irregular (in one specimen collected in April these are distinct and orange); on each elytron an oblique vermillion vitta starts on clavus at apex of scutellum and covers a little more than median third, is continued across elytron from just above middle of claval vein to outer margin where it is broadened, a tiny black spot in lower posterior corner of vitta and a large one in base of inner apical cell. Crossveins and adjacent longitudinal veins both anteriorly and posteriorly broadly reddened giving appearance of vitta across apical area, apices yellowish semihyaline. Above white, semihyaline, shining. Below creamy white, apex of beak red, tarsal claws black.

Male genitalia.—Style with large slender foot, posterior point longer than basal width of foot and curved out at apex, serrate on inner apical two-thirds; anterior point projecting laterad, less than a right angle; heel prominent, rounded; base evenly curved, forming semicircle with basal half of posterior point. Aedeagus short and straight, in ventral view square-shafted with heavy curved lateral projections from apex, in lateral view with small dorsal tooth before apex and prominent lateral apical processes projecting dorsad; pygofer process heavy, almost straight, turned slightly ventrad, apex slightly exceeding pygofer, pointed, inner margin serrate

Length: 2.5 mm.

Described from specimens from Hocking Co., Ohio, collected by D. J & J. N. Knull. Male holotype, April 17, 1938; paratype, June 1, 1938; June 28; allotype and paratypes, August 31, 1944; September 14, 1944, and September 16, 1943.

Erythroneura geronimoi n. sp.

In maculata group near *E. biramosa* Beamer and *E. bigemina* McA., but with different head and pronotal markings; aedeagus with spines, and style differently formed.

White ground color with bright orange markings as follows: vertex with short transverse bar before apex, a pair of median basal prongs extending just above middle; eyes pale; pronotum with short blunt median Y on disc, triangular vitta behind either eye; scutellum with basal angles yellow, narrowly outlined with red, apex orange. Elytra: clavi with narrow basal hook-shaped mark and apical fourth; coria with small rounded spot on costa before humeral angle, angulate vitta surrounding costal plaque, becoming enlarged to somewhat diffuse before red crossveins; a large black spot at posterior end of plaque and a large one in base of cell M_4. Apical cells fumose. Below orange markings above antennal sockets, remainder creamy white.

Male genitalia.—Style with broad base, heel about a right angle, anterior point less than right angle, posterior point more than half as long as base of foot, narrow, sharp, meeting base at less than right angle curve. Pygofer hook long and slender, reaching beyond pygofer, curved gently in from base, then out on apical half. Aedeagus of medium length, straight in lateral and ventral view, a pair of lateral narrow spines arises at base behind aedeagus and extends laterodorsad. These spines vary in length but are usually evident. Those of the holotype which are figured are more pronounced than in most specimens.

Length: 3.25 mm.

A large series taken from oak, Chiricahua Mts., Arizona, by D. J. & J. N. Knull. Male holotype, allotype and paratypes, September 14, 1938, and additional paratypes, July 26, 1937. Ten paratypes in collection of The Ohio State University.

Named for Geronimo, chief of the Chiricahua band of Apaches.

Erythroneura ohioensis n. sp.

In the obliqua group, resembling *E. rufostigmosa* Beamer and *E. juncea* Beamer, but aedeagus with ventral basal spine and style with shorter, stouter posterior point.

Robust, pronotum one-third longer than vertex, venation of obliqua type. Eyes black, ground color creamy white with red dorsal stripe darkened interiorly, apical cells and spots before reddened crossveins fumose. On vertex, stripe, which extends over to face, projects laterally toward anterior corner of eye, and almost touches eye at base; gradually broadens on pronotum, somewhat irregular on sides; scutellum entirely dark; all of clavus except small pale humeral

area, orange red, darkened in scutellar area and inner middle, narrow orange red stripe on corium along inner vein on posterior two-thirds, stripe along costal margin from base to translucent orange plaque, broader and more opaque below plaque to crossveins. Below face reddish, lateral pale area above eyes in which is included a red prong above each antennal socket; cheeks pale, also venter and legs in female, in male abdomen darkened slightly ventrally, dorsum of abdomen with anterior segments black, showing through elytra.

Male genitalia.—Aedeagus from lateral view short, slender, gently curved dorsad, a short sharp baso-ventral prong; from ventral view straight, narrow, sharply pointed apex; style with medium foot, heel sharply projecting, base broad, anterior point projecting slightly laterad, about a right angle, posterior point broad at base, about half as long as base of foot, sharp.

Female.—Last ventral segment five times as long as preceding at middle, narrowed abruptly on apical third to produced median rounded lobe; black-tipped ovipositor slightly exceeding pygofer.

Length: 3 mm.

Male holotype, allotype and paratypes, Delaware Co., Ohio, April 30, 1944, D. J. & J. N. Knull; other paratypes same locality on following dates: April 25, 1943; April 26, 1944; May 6, 1943; July 8, 1942; September 19, 1943, and October 3, 1943. Six paratypes in collection of The Ohio State University.

Erythroneura kennedyi n. sp.

A member of the comes group in which it is near to *E. vaga* Johnson in male genital characters and between *E. omaska* Robinson and *E. beameri* Robinson in external appearance.

General ground color white marked with red. Vertex with median pale longitudinal oval reaching almost to apex of head and lateral basal oval spots, half size of median, entirely red margined, eyes dark. Pronotum with median Y-shaped mark, base narrow and longer than arms, touching both margins, a long even mark behind each eye, almost reaching hind margin Scutellum, basal angles yellow, narrowly red-margined, apex red with a transverse white bar above it and space between basal angles white. Elytra with irregular zigzag vittae from humerus to crossveins with lateral narrow oblique extension below base and at anterior margin of plaque, a black dash parallel to them at lower edge of plaque; apex of clavus red, crossveins and adjacent longitudinal veins carmine; apical cells distinctly infuscated a short distance below crossveins, M_4 paler on disc; black spot at base of M_4 scarcely distinguishable from infuscation; and small distinct round spot at apex of R_3 Below, oval area either side on apex of head pale, red-margined, face pink, especially on margins, and clypeus red, remainder yellowish white, mesosternum and abdomen somewhat darkened; in male lateral portions of valve darker, and apices of plates black; in female apex of ovipositor black.

Genitalia.—Pygofer hook U-shaped, outer process almost as long as inner and about twice as broad. Foot of style small, heel prominent, base curved, anterior point very large, constituting about one-third width of foot, posterior point as long, but much narrower. Aedeagus long and slender, bifid at apex, arms forming transverse curved bar from ventral view and each arm one-fourth length of shaft, shaft straight, a pair of heavy dorsal spines arises behind shaft and extends parallel with it about two-thirds its length; separated from shaft at base by twice width of shaft. In some specimens a pair of stout spines arises anterior to base of shaft, in others this appears only as a lump.

Length: 3 mm.

This interesting leafhopper is named for Professor C. H. Kennedy.

Male holotype, allotype and paratypes, Pickaway Co., Ohio, February 20 and March 31, 1934, J. S. Caldwell; paratypes, Richland Co., Ohio, October 6, M. Auten. Five paratypes in collection of The Ohio State University.

Erythroneura vagabunda n. sp.

In the comes group near *E. asa* Robinson in genital characters and near *E. delicata* var. *accepta* McA. externally.

Background yellowish white, with orange to red markings. Vertex with median oval pale area and smaller circular area either side, narrowly red-margined. Pronotum, median Y with short base, longer arms not reaching anterior margin, dark color beneath showing through on

disc, broad irregular mark behind each eye. Scutellar basal angles yellow, narrowly red-margined, tip red. Elytra semihyaline, markings narrow, irregular, broken. Clavus with usual anchor-shaped basal mark, a black spot at suture, and small spot filling apex; corium with oblique dash on costal margin near base, another arising at anterior end of costal plaque enlarging toward middle of claval suture and angling to base of cell M_4. An oblique black dash at posterior end of plaque, obscure black spot in base of cell M_4, a definite one in apex of R_3, and apical cells infuscated some distance below red crossveins. Longitudinal veins white below crossveins, reddened a short distance above crossveins. Below sordid yellowish white, dorsum of abdomen and mesonotum black. Edges of front, clypeus and area around bases of antennae reddened.

Male genitalia.—Aedeagus from ventral view three-pronged, the median or shaft prong rough apically; pair of stout ventral processes straight, as long as shaft and parallel to it; pygofer hook U-shaped, outer arm a little thicker than and almost as long as inner. Foot small, heel prominent, base straight, anterior point short, about size of heel; posterior point heavy and twice as long as anterior point, shorter than base and meeting it at less than right angle.

Distinguished particularly by black dorsum of abdomen showing through elytra, black mesonotum and black spot at middle of clavus at elytral suture.

Length: 3 mm.

Male holotype, Lawrence Co., Ohio, April 29, J. S. Caldwell; allotype, Scioto Co., Ohio, June 17, 1944, D. J. & J. N. Knull; and paratypes from Hocking Co., June 1, 1938, D. J. & J. N. Knull; Jackson, Ohio, April 1, 1934, J. S. Caldwell; Chesapeake, Ohio, April 29, 1934, J. S. Caldwell; and Decatur, Ga., May 5, 1934, M. Auten. Two paratypes in collection of The Ohio State University.

Erythroneura noncincta Johnson

E. tricincta var. *noncincta* Johnson, Ohio Jour. Sci. 34: 261, 1934.
E. calycula var. *noncincta* Beamer, Univ. Kans. Sci. Bull. 24: 271, 1936.

Dr. Beamer stated in the above reference: "This is a variety of doubtful validity. . " As a fairly large series has been collected since its description, and also since the inner male genitalia show distinct characters, this variety is raised to specific rank and perhaps the shadow of doubt concerning its validity may be erased.

Male genitalia.—Pygofer hook U-shaped, with outer arm very short, scarcely one-fifth length of arm and of equal thickness; foot of style medium, heel small, base evenly curved; anterior point broad, longer than width of foot at narrowest place; posterior point short and sharp; aedeagus on dorsoventral view broad; shovel-shaped, with short lateral spine projecting either side, one-half distance from base, ventral processes curved toward shaft, slightly exceeding it, enlarged on outer half to twice basal width and tapering to sharp apices.

A male from Hocking Co., Ohio, April 15, 1934, J. S. Caldwell, is made an allotype and placed in the collection of The Ohio State University.

Xestocephalus piceus Osborn

Ohio Biological Survey Bulletin 14, p. 244, 1932.

The male is robust, uniformly dark brown above with exception of paler head, hyaline dots at inner middle and apex of clavus, and center of inner apical cell, square brown spot at costal margin just above crossvein surrounded by semicircular hyaline area. Below face, thorax and legs but for darker hind tibiae, straw-colored, abdominal segments dark with pale margins, and hairs of plates pale.

Resembles *X. brunneus* V. D. but is darker in color, larger and more robust. Taken in association with females exactly like type.

Length: 3.1 mm.

Male allotype, Hocking Co., Ohio, August 31, 1944, D. J. & J. N. Knull, and two males, September 14, 1944, in collection of The Ohio State University.

Dr. E. D. Ball, Jour. Wash. Acad. Sciences 22: 19, 1932, made *Twiningia irrorata* (Osborn) a synonym of *T. pellucida* (Ball). Examination of the type shows *T. irrorata* (Osb.) to be distinct and readily separable from *T. pellucida* (Ball) in a number of characters.

Unless stated otherwise type material is in collection of author.

A DESCRIPTION OF CALINELLA OPHIODONTIS N. SP. (TREMATODA, MONOGENEA) FROM THE LING COD, OPHIODON ELONGATUS GIRARD

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During the summer of 1942 a large specimen of *Ophiodon elongatus* was taken at Friday Harbor, Washington, of which the oral cavity was found to contain great numbers of a copepod, apparently a species of *Lepeophtheirus*. Adherent to these, in turn, were numerous adults, young, and eggs of a small, monogenetic trematode. Examination of the worms demonstrated that they markedly resembled members of the genus *Calinella* Monticelli, 1910. In a number of characters, however, they differed from previously described species of this genus. Accordingly, the worm is here considered as a species hitherto uhrecognized for which the name *Calinella ophiodontia* is proposed.

SPECIFIC DIAGNOSIS

Calinella ophiodontis n. sp.

Udonellid with the characters of the genus *Calinella*. Of relatively large size; adults averaging 1.5 mm. in length, 0.25 mm. in breadth, with a posterior sucker 0.2 mm. in diameter. The male reproductive system contains a large seminal vesicle which takes the form of a double, tandem pouch. The ovary is about two-thirds as large as the testis, and a seminal receptacle is present connecting with the oviduct. The egg is 0.15 x 0.07 mm. and is equipped with a polar filament several times its length which ends in an attachment disk about 0.08 mm. in diameter (Fig. 3).

Locality: Friday Harbor, Washington.

Host: *Ophidon elongatus* Girard.

Location in host: On copepods in the oral cavity.

Type specimen: U. S. N. M. Helminthological Collection No. 36903.

DESCRIPTION

Calinella ophiodontis (Fig. 1) is a small cylindrical worm with a ringed cuticle covering its surface. At the posterior end of the body is a large, flattened sucker into which open many unicellular glands massed in the posterior part of the body. On the ventral surface, near the posterior end of the pharynx and commonly slightly to the right of the midline is the genital pore. On the ventral aspect of the anterior tip lies the buccal opening (Fig. 2) surrounded by a number of papillae or processes and equipped with a pair of small suckers. It opens into a thin-walled, prolapsed, buccal cavity, about which a number of apparently glandular cells can be detected. The buccal cavity is followed by a large, muscular pharynx which is fully protrusable. No esophagus is present, the pharynx leading immediately to a saccular intestine which extends to the posterior sixth of the body, and is more or less reflected dorsally about the genitalia. A small, dorsal excretory vesicle has occasionally been observed to open through the dorsal body wall at about the level of the posterior part of the uterus; other portions of the excretory system have not been identified.

The testis (Fig. 1) is an oval structure lying just posterior to the midlevel of the body and averaging 0.24 mm. in length by 0.19 mm. in breadth. From its left, anterior, ventral margin a vas deferens arises. This crosses the ovary obliquely and proceeds toward the genital pore to the right of the midline of the body. Near the posterior end of the uterus it swells into a vesicle,

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narrows, then enlarges into a second vesicle, and finally resumes its original diameter before joining the terminal end of the uterus, just posterior to the genital pore. As sperm are concentrated in the two enlargements it seems probable that these, together, make up the seminal vesicle. The short length of vas deferens (ejaculatory duct) external to these vesicles is ensheathed by a cluster of cells which may function as a prostate gland.

The ovary (Fig. 1), lying immediately in front of the testis, is slightly smaller than the latter, averaging 0.15 mm. in length and 0.20 mm. in breadth. From the left, ventral, anterior surface an oviduct arises and almost at once becomes swollen into a pouch, commonly containing a single mature ovum. The duct narrows and crosses the left, ventral surface of the ovary to the posterior margin where it is joined by a small duct from the seminal receptacle which lies between the ovary and testis. It abruptly bends forward and continues along the left margin of the ovary, receiving a duct from the yolk reservoir which lies ventral to the left-hand side of the ovary. This reservoir is formed by fusion of a right and left posterior, and a left anterior, yolk duct collecting material from the vitellaria surrounding the intestine. Anterior to the ovary the oviduct takes a somewhat oblique course to the midline of the body and becomes a thick-walled vesicle closely enveloped by numerous Mehlis' glands. It is questionable whether this vesicle can properly be considered as a cotype since it is always smaller in diameter than the completed egg. Beyond this structure the oviduct continues as a thin-walled uterus divisible into three sections: a pouch containing the attachment organ, a coiled, narrow portion containing the polar filament, and a distal sac containing the body of the egg. These divisions are detectable even when no egg is present. The saccular portion of the uterus is directed toward the right-hand side of the body. It narrows sharply and joins the vas deferens just before terminating at the genital pore.

It has been impossible to determine anything about the structure of the nervous system.

DISCUSSION

Guberlet (1936) in discussing *Calinella myliobati* raises the question of whether this worm should be included in the genus *Calinella* citing chiefly the paucity of North American records of Udonellidae and the somewhat distinctive arrangement of the vitellaria in this species. Since the parasitic fauna of North America still remains so incompletely surveyed the absence of records of this group can scarcely be adequately weighed at present. It is, also, doubtful whether any weight should be given to the arrangement of vitellaria in arriving at a generic distinction since, as Manter has shown (1926), this character may be variable within a single species. There could be little reason, then, for subdivision of the genus *Calinella* on the basis of our present knowledge. Indeed, quite the opposite view is taken by Price (1938) who regards *Calinella* as a synonym for *Udonella*.

In size, in form of the vas deferens and related structures, and in size and form of the egg there is certainly enough difference between *Calinella myliobati* and

EXPLANATION OF PLATE

All stated magnifications are those at which the figures were drawn; reduction in reproduction is indicated by a 5 centimeter figure accompanying the plate.

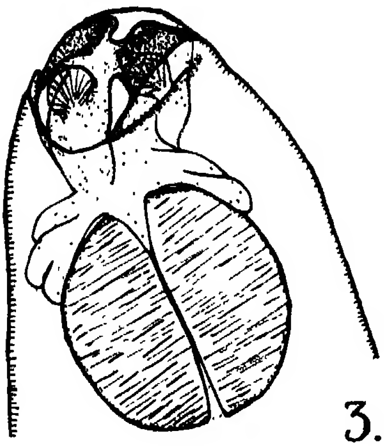
FIG. 1. Ventral view of entire worm with the yolk reservoir figured as semi-transparent to show the underlying structures. × 150.

FIG. 2. Anterior end showing buccal organization. × 250.

FIG. 3. Egg, removed from surface of copepod to show expanded attachment organ. × 200.

LIST OF ABBREVIATIONS

M—Mehlis' glands
O—Ovary
OO—Ootype
P—Prostate glands
SR—Seminal receptacle
SV—Seminal vesicle
T—Testis
U—Uterus
VD—Vas deferens
VF—Vitelline follicle
YR—Yolk Reservoir



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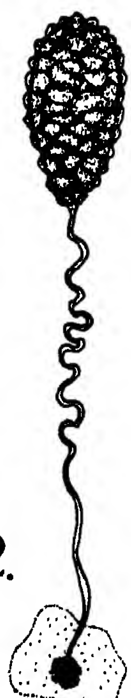

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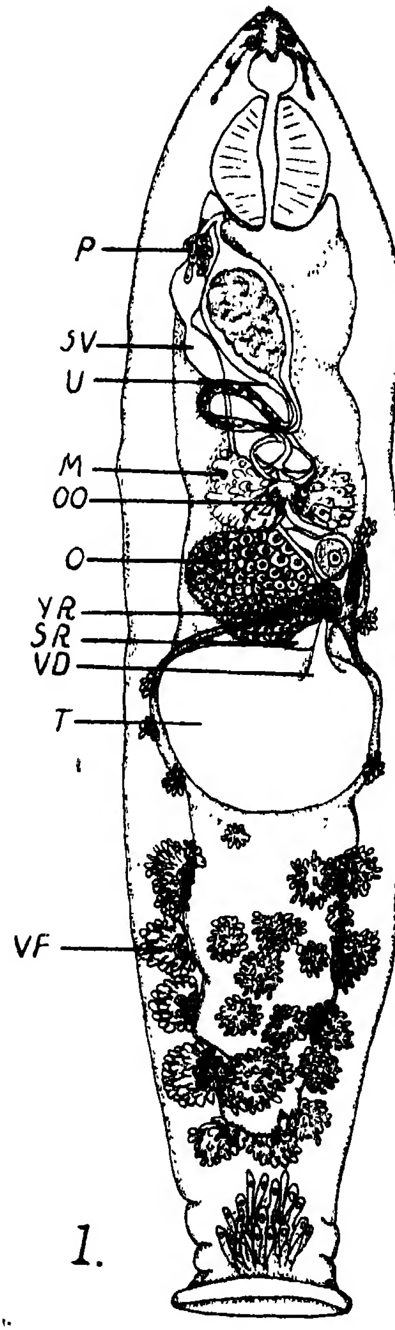

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Calinella craniola to warrant recognition of two species. The same is equally true of *Calinella ophiodontis:* it possesses fully the generic characters of *Calinella*, but it differs consistently and significantly from both *Calinella craniola* and *Calinella myliobati*. It may be distinguished from both species by the relatively large ovary and by the extremely long filament and the complex attachment organ of the egg. The form of the terminal part of the vas deferens is quite unlike that of *C. craniola* and differs somewhat from that of *C. myliobati*. The possession of glands opening into the posterior sucker has not been reported in this genus, though known in related forms. A seminal receptacle is not reported from *C. craniola*, incompletely described in *C. myliobati*, and definitely present in *C. ophiodontis*. Finally, the size of *C. ophiodontis* is considerably greater than that of *C. craniola* and slightly above that of *C. myliobati*. Taking these points into consideration it is scarcely possible to identify *Calinella ophiodontis* with either *Calinella craniola* or *Calinella myliobati*.

SUMMARY

Calinella ophiodontis n. sp. is described from *Ophiodon elongatus*. It is shown to differ from previously described species in size, in the possession of pedal glands, and in certain characters of the reproductive system and of the egg.

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REVIEW PAPERS

(Papers appearing in this section are invited reviews of subjects of wide current interest.)

A REVIEW OF THE PROBLEMS OF SULFONAMIDE CHEMOTHERAPY

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Every since the development of systematic bacteriology and the rapid growth of the germ theory of disease, man has been engaged in an untiring search for agents which would specifically destroy the offending organisms. Up to the time of Ehrlich, that search had been more or less fruitless. Ehrlich approached the problem from a fresh point of view, and it is to him that we owe our modern concept of the chemotherapy of disease. His theory was expressed as "therapia sterilisans magna." He chose to direct this "sterilizing therapy" at the dread scourge of syphilis, and in 1907 he announced the discovery of salvarsan. Ehrlich's was the first planned attack upon a specific organism by means of a specific drug. Up to that time, quinine was the only specific therapeutic agent known to medicine, and it had been used empirically. This date, 1907, then marks the beginning of the modern clinical attack upon disease-producing microörganisms.

In the next year, an obscure Australian chemist, Gelmo, synthesized p-aminobenzenesulfonamide. Chemotherapy was the farthest thing from his mind. He was searching for dye intermediates, and the astounding potentialities of his new compound remained unknown for more than twenty-five years. It was not until 1932 that two German workers, Meitzsch and Klarer, experimenting with the possibilities of various dyes as antiseptics, noted that Gelmo's compound was very effective in preventing death in mice infected with the β-hemolytic streptococcus. Little further work was done along the lines suggested by this discovery until 1935 when another German worker confirmed and extended the earlier observations and a new era in chemotherapy was opened. The compound with which he worked was not Gelmo's original p-aminobenzenesulfonamide but a derivative known as prontosil. It was shortly learned that the extra chemical group in prontosil was not necessary for its activity against the streptococcus and he named the parent group (Gelmo's original compound) sulfanilamide. The German scientist who thus opened the door to modern chemotherapy was named Domagk. In the same year three English workers, Buttles, Grey and Stephenson, confirmed these observations and made them known to the world. Domagk was awarded the Nobel Prize and it is a significant comment on trends then prominent in Germany that Hitler refused to permit Domagk to receive the award.

When we examine the structure of sulfanilamide, we see at once that a host of substitution products are possible from a strictly chemical point of view. It has been estimated that some 7,000 different compounds related to this nucleus have been prepared and tested biologically. Out of this huge amount of work has come a number of observations of fundamental importance with reference to the activity of the substitution products of sulfanilamide. Then it was learned that neither substitutions on the ring other than the p-amino group nor modifications of the sulfoxide radical would yield compounds which were effective against the bacteria. There remained then only the possibility of substituting the amide nitrogen. A large number of amido-substitution products have been prepared

but only a few of these have come into the practice of medicine. The first one of any importance was sulfapyridine, introduced in England in 1939. It was sylfapyridine which really established the value of this group of drugs in medicine, for sulfapyridine was effective against the pneumococcus, the most dramatic and one of the worst scourges of mankind. In 1940 American chemists gave us sulfathiazole, and in 1941 sulfadiazine appeared. Since 1941 there have been but few additions to the sulfonamide group of drugs. The substituted nucleus of sulfadiazine has been slightly modified and two of its relatives, sulfamethazine and sulfamerazine, are receiving the tests of their clinical value today.

It was further noted that substitution on the amino nitrogen made the compounds difficult to absorb from the gastrointestinal tract. Such compounds were found, however, to be effective against many types of bacteria which are either

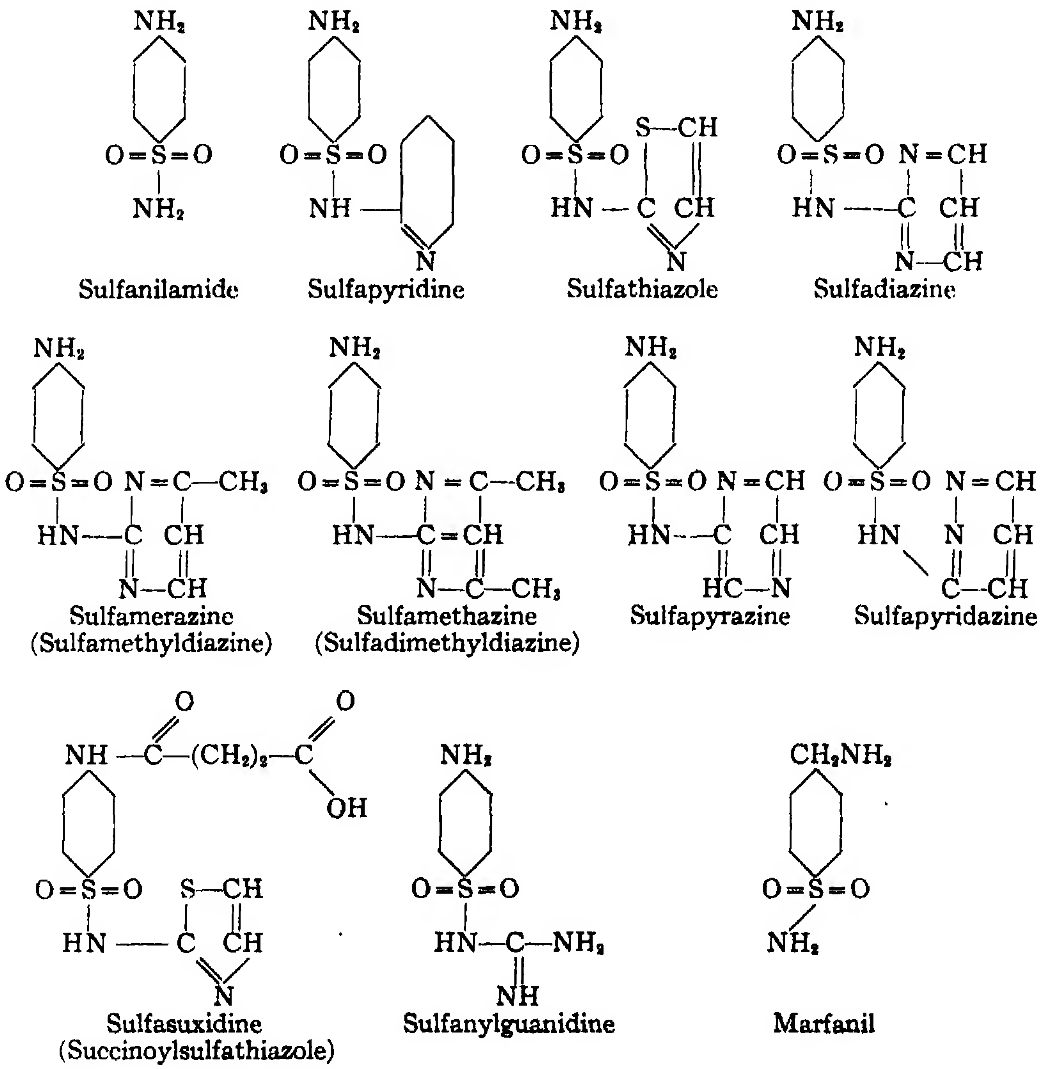

FIGURE 1. THE STRUCTURAL RELATIONSHIPS OF THE SULFONAMIDES

normal inhabitants of the gastrointestinal tract or produce diseases peculiar to that system. Two of these compounds have been of some use in medicine. They are sulfasuxidine and sulfanylguanidine. A third compound of this latter type known as marfanil has been employed by the Germans in the prevention and treatment of wound infections. Captured samples of this drug have been studied and its structure is known. Preliminary reports indicate that marfanil is more effective for the use noted than any of the previously known sulfonamides.

The structural relationships of all of these drugs are indicated in Figure 1.

PHARMACOLOGY

A. Absorption and Fate of the Sulfonamides.

All of the sulfonamides in which there is no modification of the amino nitrogen are relatively rapidly absorbed from the intestine. Maximum blood levels are attained in from 3 to 6 hours, following a single dose of any of the group. For this reason it is seldom necessary to administer the drugs by any other route than the oral. In certain specific cases, as, for example, when the patient is vomiting or in the presence of an overwhelming infection demanding heroic treatment, it is sometimes desirable to administer the drugs parenterally. With the exception of sulfanilimide, all of the free compounds are too insoluble for parenteral administration but for this purpose there are available soluble sodium salts of sulfapyridine, sulfathiazole and sulfadiazine.

All of the sulfonamides after absorption are rapidly distributed to all organs and tissues and to all of the extra-vascular fluid compartments. Concentrations attained are, in general, approximately 20 per cent lower than the concentration in the blood. One important exception to this general statement should be noted in the case of sulfathiazole. For some unknown reason, the concentration of sulfathiazole in the cerebrospinal fluid of the normal individual remains at a level represented by 10 per cent or less of the level in the blood. Recognition of this fact is important in the selection of a drug in the treatment of meningitis

After the sulfonamides have been distributed throughout the body as noted above, very little happens to alter their chemical nature. All of them are acetylated by the liver to the extent of about 15 per cent of the total concentration in the blood. Recently it has been noted that certain members of the group tend to combine to a greater or lesser degree with the plasma. This action is spoken of as plasma-binding capacity. With sulfathiazole this occurs to the extent of about 25 per cent of the total plasma concentration; with sulfadiazine, to the extent of about 50 per cent; and with sulfamethazine, about 75 per cent. The variations in the plasma-binding capacity may be of significance with reference to the effective blood level in any given infection but the exact significance is not fully understood at the present time. Certain conditions existing in areas where infection is present or is likely to occur operate to lessen the effectiveness of the drugs. Among these must be mentioned collections of serum and the presence of pus. How these extraneous factors affect the metabolism of the sulfonamides is not known.

The chief route of excretion for all of the sulfonamides is via the urinary tract. Certain complications of great significance in the therapeutic use of the sulfonamides may occur as a result of this pathway of excretion. More detailed reference to this phenomenon will be made below.

B. Mechanism of Action.

The mechanism by which the sulfonamide drugs act to combat infectious processes presented a very difficult but interesting problem in bacteriology. Certain fundamental observations with reference to the classical theories of antibacterial action were soon made. They were as follows:

1. The drugs act by slowing the growth of the bacteria rather than by killing them outright; their action is bacteriostatic rather than bacteriocidal.
2. The drugs cause no potentiation nor inhibition of immunologic responses nor of the phagocytic mechanisms of the host.
3. The sulfonamides have no effect which could be interpreted as concerned with the neutralization of bacterial toxins.

In the light of these negative findings, it was necessary to postulate and study other possible mechanisms. The results of such studies may be briefly summarized as follows: The sulfonamides compete in the metabolism of the bacterium with some substance which is essential to the normal growth and multiplication of the organism. This hypothetic substance was definitely found to be p-aminobenzoic acid, known to the elect as PAB. Upon comparing the sulfonamides and PAB, it might be said somewhat facetiously, that the poor bacteria, never having had a college course in organic chemistry, are unable to distinguish between p-aminobenzoic acid and p-aminobenzene sulfonamide, and in attempting to utilize the former starve to death in the process. It is probably unwise to treat such an important discovery so lightly for, if it is possible to confuse the bacteria in this respect, then it is equally possible that a little research may disclose other substances which are essential to the well-being of the organisms. Synthetic compounds resembling these essential metabolites may then be developed and offered as ineffective substitutes for the essential metabolites to the detriment of the bacteria. The possibilities inherent in such an idea are so far-reaching that they stagger the imagination. Suffice it to say that already a great deal of research has been done along the lines suggested here. It is indeed fortunate that such a fundamental discovery has been made for it has been suggested only recently that the sulfonamides have probably been developed to their maximum extent. On the basis of certain careful physico-chemical observations, it has been predicted that sulfadiazine exhibits the maximum antibacterial action which can be developed by any derivative of the parent sulfonamide nucleus.

CLINICAL APPLICATION

A. Organisms Affected:

Following the initial wave of enthusiasm which greeted the introduction of the sulfonamides into the practice of medicine, it became quickly apparent that these new compounds were not panaceas. It was shortly learned that the sulfonamides were effective against a definitely limited number of organisms and that all of them were not equally effective against even these. Among the diseases which are most adequately controlled by the sulfonamides are those which are caused by the β-hemolytic streptococcus, the pneumococcus and the gonococcus. Among those diseases which may be fairly satisfactorily treated by the sulfonamides are those caused by the meningococcus, the staphylococcus, and the α-hemolytic streptococcus (viridans). It is thus apparent that the field of usefulness is limited almost entirely to the coccal infections. Infections in which the etiologic agent is a bacillus and which respond to the administration of the sulfonamides are uncommon. Chief among them are infections produced by *Escherichia coli*, and by the dysentery bacilli. The gas gangrene group of bacilli are only moderately susceptible. It must be emphasized that the sulfonamide drugs are totally ineffective against the causative agent of rheumatic fever and against the organisms causing typhoid fever, typhus, diphtheria, tuberculosis and syphilis. In addition to these, furthermore, none of the known virus infections responds to sulfonamide therapy. These include influenza, "virus" pneumonia, measles, smallpox and many others. Table I compares their relative effectiveness against the common organisms.

B. Special Cases:

1. Streptococcal Infections.

a. β-Hemolytic Streptococcus.—This organism is responsible for so-called strep throat; for one of the dreaded forms of blood poisoning; and very probably for scarlet fever. Once it has taken hold in a susceptible individual it goes like wildfire and the patient when first seen is usually acutely and dangerously ill. Complication follows complication and, if the patient is able to withstand the onslaught and survive, he must usually face a long period of debility.

b. α-Hemolytic Streptococcus.—This organism commonly known as *Streptococcus viridans*, or the "green-producing" streptococcus, is a common cause of upper respiratory infections of the type usually associated with the common cold and its sequellae. We have already noted that the sulfonamides are of limited value in the management of infections caused by this organism, and the use of these drugs in the common cold is generally of little value

TABLE I

The Comparative Susceptibility of the Common Organisms to the Various Sulfonamides

Organism	Sulfanilamide	Sulfapyradine	Sulfathiasole	Sulfadiazine
β-hemolytic Streptococcus	++++	+++	+++	++++
α-hemolytic Streptococcus	++	++	++	++
Diplococcus pneumoniae (pneumococcus)	±	++++	++++	++++
Neisseria intracellularis (meningococcus)	++	++	++	++
Neisseria gonorrhoeae (gonococcus)	++	++	+++	+++
Staphylococcus	±	++	++	+++
Escherichia coli (urinary tract)	+++	++	+++	+++

One of the most terrible diseases known to medicine (fortunately, a relatively uncommon disease) is subacute bacterial endocarditis. This is a slowly progressive disease which nearly always attacks only those whose hearts have been damaged by rheumatic fever. It has been, up to the present era, a uniformly fatal infection. As one famous pathologist puts it, "The heart is beating muffled marches to the grave." Great hopes were held for its treatment when the sulfonamides became available, but disappointment and despair have followed their use. In one outstanding paper discussing the treatment of 67 cases of this disease, in which all of the sulfonamides and all adjuvant forms of therapy were used, the concluding sentence reads, "All sixty-seven patients are dead."

2. Pneumococcal Infections.

Prior to the advent of sulfapyridine, somewhere between 30 and 50 per cent of patients suffering from pneumonia died. Sulfapyridine alone reduced this appalling mortality to about 12 per cent and it was at once hailed as the "miracle drug." If no other benefits had resulted from the use of the sulfonamides, this victory alone would have been sufficient reward for the tremendous effort which has been expended in the development of these drugs. Sulfapyridine is no longer used in medicine, because both sulfathiazole and sulfadiazine are equally effective, and both of the latter are much less toxic to the patient than is sulfapyridine. In addition to the tremendous reduction in mortality it is apparent at once from this clinical picture that the morbidity has also been strikingly decreased. In a word, the fortunate patient who recovered from pneumonia in the pre-sulfonamide era was destined to spend long weeks of convalescence before he was able to return to anything resembling normal existence. Today he may be as "good as new" in as short a time as three weeks after the onset of the illness.

3. Gonococcal Infections.

Gonorrhea has always been held somewhat lightly in the minds of men. This attitude has prevailed in spite of the fact that gonorrhea rendered thousands upon thousands of women incapable of child-bearing. The misery, both physical and mental—and spiritual—produced by the gonococcus must forever remain incalculable. The sulfonamides have gone far in reducing this scourge, but the very nature of the disease and the circumstances surrounding its transmission work continuously against any method of treatment. We shall have occasion under another heading to refer again to the gonococcus.

Prior to the availability of the sulfonamides, an uncomplicated case of gonorrhea which was given the best therapy available could be cured in a matter of weeks. When the sulfonamides are used in a similar case today, the cure is literally a matter of hours. Here again we see strikingly illustrated the tremendous importance of these drugs.

C. PROPHYLACTIC USE.

It was natural that drugs which were so effective in the cure of certain diseases should be tried for the purpose of preventing these diseases from developing. For a long period of time after the introduction of the sulfonamides, their prophylactic use belonged in the category of "armchair" therapeutics. No one had any real information as to their efficiency in the prevention of disease and such use aroused a small storm of protest from those who were already beginning to realize the complications which might arise from the development of fastness in the organism and sensitivity in the patients. These men argued that before prophylactic use was justifiable, it must first be demonstrated that a sufficiently high degree of morbidity could be prevented to justify the danger of the production of sensitivity in those receiving the drugs, and to justify the development of "carriers" of sulfonamide-fast organisms. The multitude of variables presented in the consideration of these two problems has thus far defied analysis. The war with its consequent crowding together of large groups of men under conditions which have long been realized to be ideal for the development and spread of epidemics, made the prophylactic use of the sulfonamides under certain circumstances mandatory. For example, an epidemic of scarlet fever began on Navy Pier in New York City. At once a large section of the personnel was given sulfadiazine in small daily doses. The case incidence of scarlet fever in the treated group promptly fell to zero. Another trial of prophylactic value was made in a Southern army camp. Sulfathiazole was administered to each man who "signed out" in the evening, and a similar dose was given when he returned to camp. In this camp, prior to the introduction of routine sulfathiazole administration, the incidence of gonorrhea was 171 cases per 1,000 men per year. Following the prophylactic use of sulfathiazole, the case incidence dropped to 8 per 1,000 men per year. Many more such instances could be cited. However, they all point toward the same conclusion. It is possible by the controlled prophylactic administration of a sulfonamide to reduce materially the incidence of infection by any bacterial agent which is ordinarily susceptible to the sulfanomides. Thus the fact of prophylaxis is established. It must be emphasized, however, that the two dangers inherent in sulfonamide prophylaxis have not been adequately evaluated.

D. TOXICITY

1. General Incidence of Toxic Reactions.

In the early years of sulfonamide chemotherapy, it was difficult to evaluate the incidence of total toxic reactions to the administration of these drugs. However, with the passing years it has become possible to give what is believed to be

a reasonably correct estimation of reaction incidence. The over-all reactions may be summarized roughly as follows (excluding the "mild" group in Table II):

Sulfathiazole	18 per cent
Sulfapyridine	16 per cent
Sulfanilamide	12 per cent
Sulfadiazine	10 per cent

In certain clinics it has been possible by meticulous attention to all details of therapy to reduce the over-all incidence of toxic reactions to figures appreciably below those cited. Table II gives a detailed analysis of the reactions which have been reported, together with an estimate of their distribution among the various sulfonamides. In general, those labeled "mild" do not contraindicate the further administration of the drugs; the label "moderately severe" should give reason

TABLE II

THE PERCENTAGE DISTRIBUTION OF THE MORE COMMON REACTIONS TO THE SULFONAMIDES

	Sulfanilamide	Sulfapyradine	Sulfathiazole	Sulfadiazine
	%	%	%	%
MILD				
Nausea and vomiting	25–40	40–60	6	0 7
Dizziness	50–60	50–60	5	rare
Mild hemolytic anemia	3	rare	rare	rare
Cyanosis	90–100	50	rare	none
MODERATELY SEVERE				
Acidosis	2	rare	rare	rare
Fever	10	4	6	3
Rash	2	2	6	2 1
Hematuria (microscopic)	?	–	4	5
SEVERE				
Leukopenia	0 3	0 6	1 6	1 2
Agranulocytosis	0 1	0 3	rare	rare
Anuria or oliguria	none	0 3	0 7	1 5
Jaundice	1 8	0 6	rare	rare

for stopping the drug unless to do so would endanger the patient's life; the appearance of these reactions called "severe" makes the cessation of administration mandatory.

Sulfadiazine is the most important of the sulfonamides today and has for most infections supplanted all the rest.

It is unwise to try to draw many conclusions with reference to the significance of these toxic phenomena from the bare figures given here. The severity of a reaction varies directly with the seriousness of the disease process which instituted the administration of the drug in the first place. These tables and figures are included merely to permit a general concept of the extent and type of toxic effects which may be anticipated.

It should be pointed out that the actual numbers of individuals receiving the drugs are so great that some of the figures given in the tables fade into insignificance. Only those reactions in which there may be a large element of sensitivity involved, and those reactions referable to the kidney will be considered in any detail. The significance of the "sensitivity" group is discussed in the section dealing with the limitations of the sulfonamides.

Those reactions referable to the kidney are of sufficient importance to merit further comment. These reactions are of two types. The first type is entirely mechanical in character. As the sulfonamides are excreted, both in their free

and acetylated forms, they are concentrated in the kidney. As that concentration rises they tend to be precipitated, and crystalline compounds thus formed act to produce mechanical damage to the kidney tubules. This damage may range from slight irritation of the tubules with the appearance of a little blood in the urine, to the complete blocking of the tubules followed by the loss of the ability of the kidney to function. In addition to these mechanical effects, the sulfonamides (especially sulfadiazine) produce a chemical action on the walls of the kidney tubules. This cellular damage may also result in serious derangement of kidney function.

The greatest attention has been paid to these reactions and, if the proper precautions are taken, the incidence of serious kidney damage can be reduced almost to zero. The precautions are simple indeed and involve, first of all, careful observation of the patient's urinary output, which should be at least 1000 cc. daily. In the second place, some effort should be made to keep the urine alkaline by the administration of an alkaline salt, such as sodium bicarbonate. An alkaline urine helps to insure maximum solubility of the drug and reduces the danger of damage by crystal formation.

It should be mentioned that the "dizziness" noted in the tables may make it unsafe for the patient to carry our skilled tasks, such as driving a car or piloting an airplane. For this reason, in the Air Forces, any pilot receiving a sulfonamide is "grounded" until his treatment is finished.

E. The Limitations of Sulfonamide Therapy.

1. Organisms Not Affected.

In a previous section, the sulfonamide susceptibility of the various organisms which commonly cause disease was discussed. Little more need be said here, except to point out that the use of the sulfonamides in diseases caused by unsusceptible organisms is to be unhesitatingly condemned.

2. Sulfonamide "Fastness."

In the early days of the sulfonamide therapy of gonorrhea, it was not uncommon to see reports indicating an incidence of cure as high as 90 per cent. As time has passed, this figure has further decreased until today one is likely to be depressed by the fact that rates of cure are being reported as low as 30 per cent. These carefully controlled case-studies are supported by the passing observations of many physicians who have not studied the problem in detail. For example, one prominent urologist in a Midwestern city told me in 1941 that he had long since cured all of the gonorrhea which was curable by sulfonamide and by sulfapyridine, and that he was then working on sulfathiazole. He remarked that he hoped a new sulfonamide would soon make its appearance else he would have to resort to the old pre-sulfonamide methods. These observations with reference to the gonococcus raised the question of the development of resistance by the organisms to the action of these drugs. This problem of resistance has been studied in great detail using all of the organisms which are known to be originally susceptible to sulfonamides. As a result of such studies, it is now known that most of the susceptible organisms under the proper conditions may become completely resistant to the action of the drugs. Such resistant organisms then are said to be sulfonamide-fast.

The conditions for the development of fastness have not been completely established. It seems, however, that prolonged exposure to concentrations of sulfonamide somewhat lower than those used therapeutically, is extremely effective in producing strains of resistant organisms. It is clear this phenomenon of fastness may be especially significant, if one takes the long term view. It is at once apparent that we must consider the definite possibility of the ascendency of a whole new order of sulfonamide-resistant bacteria.

It has been shown that about 40 per cent of persons who recover from pneumonia serve as carriers of the infecting organisms for a long period of time. Many of these organisms have undoubtedly become resistant to sulfonamides during the treatment of the active disease and it has been shown that even now the incidence of sulfonamide-resistant pneumococcal pneumonia is increasing.

The illustrations afforded by the gonococcus and the pneumococcus serve as a grave warning with reference to the future of sulfonamide therapy. The possibility of the development of resistant organisms constitutes one of the chief contraindications to the indiscriminate use of the sulfonamide drugs.

3. The Problem of Sensitivity.

A number of the toxic reactions discussed above have been found to be the result of the development within the individual of special sensitivity to the sulfonamides. This sensitivity is related in some fashion to the general problem of allergy. The exact mechanism of the development of sensitivity is not well understood. It is, however, assumed that the sulfonamides react in some fashion with certain protein elements in the blood-stream, and antibodies for this new compound are then developed. The result of these complex changes is a repetition of the toxic response following immediately upon the administration of the next dose of the sulfonamide which caused the original reaction. Here again, as in the case of fastness, all the factors producing such sensitivity have not been fully determined. It is the consensus of opinion, however, that both the size of the dose and the duration of the administration are involved. Some of the reactions presumed to be sensitivity phenomena, are fever, skin rashes, agranulocytosis, and hemolytic jaundice. Some of the other reactions may also belong in this category but there is sufficient question as to their being so classified that we shall omit them from this discussion.

In the case of fever it has been noted that it is most likely to occur between the 5th and 7th days of administration. When a patient who has developed a fever receives a second course of sulfonamide drugs within the next year, he is very likely to develop a drug fever within the first 24 hours. Now the relation of duration of administration to the development of the sensitivity reaction may be pointed out. If a first course of sulfonamide therapy does not extend into the period when the fever would ordinarily be manifest, then no sensitivity would be developed so far as fever is concerned. This conclusion is not entirely valid for exceptions to it have frequently been noted. The second major factor (the size of the dose) is difficult to evaluate. The use of the sulfonamides in the prophylaxis of infectious diseases necessitates the administration of smaller doses over a long period of time. In such circumstances the incidence of reactions of all kinds is very low, generally in the neighborhood of 1 to 2 per cent. However, following the cessation of prophylactic course, it has been suggested that the incidence of these reactions believed to be sensitivity phenomena is much higher whenever it becomes necessary to give those patients full therapeutic doses of the drugs. This observation suggests that it is possible to develop sensitivity by continuous small doses without any overt toxic manifestations during such a prophylactic course. In summarizing, it may be said that there is little doubt that some of the toxic reactions to the sulfonamides are sensitivity phenomena. The exact significance of such phenomena with reference to the future of sulfonamide chemotherapy is not yet apparent. Nevertheless, the possibilities are sufficiently alarming to discourage the indiscriminate administration of the sulfonamides.

THE FUTURE OF SULFONAMIDE CHEMOTHERAPY

As time goes on and we recover somewhat from the effects of our enthusiasm with respect to the sulfonamides, their value in the practice of medicine becomes more clearly defined. This group of drugs will continue to hold an important

place in therapeutics. The indications for their use have been clearly defined but the contraindications are still somewhat debatable. It is with the latter that we must be more concerned in the future. Obviously, the use of sulfonamides in the treatment of an infection caused by an organism which is known not to be susceptible to the sulfonamides constitutes a contraindication. Among the other contraindications, may be mentioned inadequate therapy, indiscriminate prophylactic use, and administration prior to an attempt to discover the nature of the offending organism. These three errors of application invite the development of "fast strains" of organisms. They also favor the development of sensitivity phenomena in the patients receiving them. If we are to keep the development of sensitivity and the development of fastness at a minimum, then it behooves us to use the sulfonamides sparingly and only after weighing carefully all of the dangerous possibilities which may, and inevitably will, accrue from their indiscriminate use.

It is probably justifiable to say that the sulfonamides themselves have served their greatest purpose in the treatment of human ills, not by virtue of their effect upon certain specific organisms, but because they have introduced us to a new approach to the problem of bacterial infection in general--the so-called metabolic theory of bacteriostasis. There is every reason to believe that other substances essential to the welfare of a given organism will be discovered. Then compounds may be prepared which will compete with that essential metabolite to the detriment of the organism in question. From this point of view, the outlook for the future of chemotherapy is indeed bright and it is not inconceivable that some time in the near future we may hope for drugs which will rid us of all infectious diseases.

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THE EFFECT OF CHEMICAL SOIL TREATMENTS ON THE DEVELOPMENT OF WHEAT MOSAIC

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INTRODUCTION

Wheat mosaic virus, *Marmor tritici* H.[2], is unique in the fact that it is transmitted from one generation of wheat to another through the soil. Both winter and spring wheat are susceptible to infection when planted in the fall, but usually the symptoms are not noticeable until the following spring when the plants make rapid growth. In a previous communication (4) the writer reported results on the study of certain insects and nematodes with regard to their ability to act as virus vectors. Neither the insects nor nematodes considered transmitted the virus. Thus far the vector of wheat mosaic virus occurring east of the Mississippi River has not been found, and the method of inoculation when plants are grown in virus-infested soil is open to conjecture.

It is known that a soil treatment with a solution of formaldehyde in water will control wheat mosaic, as will steam sterilization (5). It also has been shown (3) that control of the disease can be obtained by heating infested soil at a temperature of 60° C. for ten minutes.

From our general knowledge of the disease it is believed that a soil-borne organism is responsible for transmission of the virus. In an attempt to elucidate this point a study was made to determine what effect certain chemicals used as insecticides and nematocides would have on the development of the disease when applied to virus-infested soil. The present paper discusses some of the results obtained.

MATERIAL AND METHODS

The soil used in these tests was collected from localities in Indiana where mosaic had seriously affected wheat over a period of many years. When treated, the soil was at a moisture content of 25 per cent and gave a pH reading of 4.8. By analysis the soil contained 25 per cent clay, 59 per cent silt, and 16 per cent sand and fine gravel.

[1]This work was conducted while the writer held the Muellhaupt Scholarship, Department of Botany, Ohio State University, Columbus, Ohio. Grateful acknowledgement is made to Dr. R. M. Caldwell of Purdue University, and Dr. Benjamin Koehler of the University of Illinois, who supplied the soil for investigational purposes. Without their aid this study could not have been undertaken. The writer is also indebted to Dr. E. N. Transeau, Dr. W. G. Stover, and Dr. C. C. Allison, of Ohio State University, for their assistance in the preparation of the manuscript. Paper from the Department of Botany, the Ohio State University, No. 478.

[2]The Latin name of the virus follows the system of nomenclature in the Handbook of Phytopathogenic Viruses (2).

Eighteen air-tight metal containers, with a capacity of 490 cubic inches, were filled to one inch from the top with virus-infested soil which previously had been passed through a screen of one-fourth-inch mesh. Six chemicals were studied at different concentrations. Calcium cyanide (granulated) was used at 1, 3, and 5 gms.; carbon disulphide at 2, 5, and 10 cc.; while chloropicrin, ethyl chloride, ethylene dichloride and methyl bromide each were used at 0.3, 1, and 3 cc. Each sample of chemical was placed in one of the metal containers, approximately equidistant from the bottom and the surface of the soil; then water was sprinkled over the surface to create a partial seal. A close-fitting, cardboard disc, which previously had been given three coats of animal glue on each side, was next inserted over the soil; and glue was used as a seal between the disc and container. This procedure was followed since the work of Godfrey (1) showed that the gases of chloropicrin and carbon disulphide do not readily diffuse through membranes of animal glue. As a check on the effect of the chemicals on the development of the plants, non-infested soil was treated in the manner described above, except that only six containers were used, one for each of the six chemicals. In each case the check soil was treated with a dosage equal to the largest amount of chemical applied to the infested soil.

At the beginning of the experiment all soil was at a temperature of 16° C., and after the containers were sealed they were placed in a greenhouse where the temperature was approximately 27° C. After seven days the discs were removed and the soil from each can spread out on separate paper sheets and placed outdoors to facilitate aeration. Strong odors of carbon disulphide, calcium cyanide, chloropicrin, and methyl bromide could easily be detected as the discs were removed from their respective containers.

The wheat was sown in No. 10 tin cans. The bottoms of the cans were perforated with holes to permit drainage of excess water. The required number of these cans were first half filled with composted soil known to be free from virus. To this was added a three-inch thick layer of the chemically treated soil in which the wheat was planted four days after the discs were removed. The treated soil from each container was placed in five of the tin cans and fifteen seeds of Purdue No. 1 wheat, a variety highly susceptible to mosaic, were planted in each can. This method has been shown by Webb (7) and confirmed by the writer to give about as much infection as when infested soil was used exclusively without the underlying non-infested soil.

After the wheat was planted all cans were placed outdoors over winter in soil trenches about eight inches deep and each series of five cans was placed in one row. There was a space of four inches between the cans in each row and sixteen inches between each row of five cans. As a control, wheat was also planted in virus-infested and non-infested soil which had not been treated with the chemicals. The outside soil was firmly pressed around each can and drainage of surface water was cared for by providing ditches in order that the soil within the cans should not become mixed.

EXPERIMENTAL RESULTS

There was a good stand of wheat and the plants were approximately six inches tall when the hard frosts and snows of winter settled. Considerable heaving of the soil within the cans caused some plants to die. No counts of plants were made in the fall, but one record from fifty cans selected at random made in the spring when the plants were making rapid growth gave an average of between eight and nine plants in each can. The diseased and healthy plants were not counted separately, but were critically examined three times up to the period when the wheat was in the boot stage. The results were recorded in a general way as: complete control; incomplete when both healthy and diseased plants were present; and no control.

The examinations revealed that calcium cyanide was more effective in controlling the disease when used at the higher concentrations. At 1 gm. there was no control; at 3 gms. control was incomplete; but 5 gms. completely controlled the disease. There were no diseased plants in the soil treated with carbon disulphide at each of the concentrations of 2, 5, and 10 cc. Chloropicrin and methyl bromide were similarly effective when used at 0.3, 1, and 3 cc. At the latter concentrations ethyl chloride was not effective, and ethylene dichloride gave only incomplete control at the two higher concentrations.

In another experiment virus-infested soil, of an amount equal to that used previously, was placed in a tight container and subjected to the fumes of naphthalene at room temperature for 17 days. The soil was placed in cheesecloth bags and suspended over the naphthalene flakes. After four days of aeration it was planted to wheat in the manner described above. Another similar quantity of soil was air dried, then mixed thoroughly with 500 gms. of rotenone powder with active ingredients of 0.75 per cent. Water was then added before the wheat was sown. No disease developed as a result of either of these treatments.

The plants grown in the non-infested soil remained healthy throughout the length of the experiment, while there was a very high incidence of disease in the virus-infested soil which had not been subjected to the chemicals. No evidence of any effect of these materials on the development of the plants was noticed. The results of these experiments are recorded in Table I.

TABLE I

EFFECT OF CHEMICAL TREATMENTS TO VIRUS-INFESTED SOIL ON THE DEVELOPMENT OF WHEAT MOSAIC*

CHEMICAL	AMOUNT USED	EFFECT ON DISEASE
Calcium cyanide (granulated)	1.0 gm. 3.0 gm. 5.0 gm.	No control Incomplete control Complete control
Carbon disulphide	2.0 cc. 5.0 cc. 10.0 cc.	Complete control " " " "
Chloropicrin	0.3 cc. 1.0 cc. 3.0 cc.	Complete control " " " "
Ethyl chloride	0.3 cc. 1.0 cc. 3.0 cc.	No control " " " "
Ethylene dichloride	0.3 cc. 1.0 cc. 3.0 cc.	No control Incomplete control " "
Methyl bromide	0.3 cc. 1.0 cc. 3.0 cc.	Complete control " " " "
Rotenone	500.0 gm.	Complete control
Naphthalene		Complete control

*Grateful acknowledgement is made to Innis, Speiden & Company for chloropicrin; to the Pittsburg Chemical Company for methyl bromide; and to The Dow Chemical Company for ethylene dichloride and ethyl chloride.

DISCUSSION

These experiments were not planned in order to find a means of controlling wheat mosaic as this already is accomplished in a practical way by the use of resistant varieties, but it did seem of interest to study what effect some chemicals which are toxic to certain organisms would have on the development of the disease. While these results are somewhat interesting, it must be remembered that more than one replication of this work might have yielded other data, but unfortunately not enough virus-infested soil was available for such an undertaking.

The results obtained indicate that the liquids previously used effectively as insecticides and nematocides were also effective in controlling the disease. Ethylene dichloride and ethyl chloride were not as effective, but nothing is known as to the efficiency of the animal glue membranes used as a seal over the fumigating chambers on the retention of these gases. It is interesting to point out that no disease developed in the soil with which rotenone dust had been mixed. In this case the soil had first been stored in a well ventilated room until dry before it was mixed with the rotenone, but this procedure was not considered to have affected the results obtained, since McKinney (6) has shown that the disease develops in virus infested and retained in an air-dried condition for three years.

The nature of the vector of wheat mosaic virus is still open to discussion. It is believed that a subterranean insect or nematode transmits the virus, and that the action of the materials used was on the vector rather than on the causal agent. There are many kinds of subterranean arthropods such as thrips, spring tails, garden centipedes, mites, and root aphids, to mention a few, which might pass unnoticed to the unaided eye while examining soil. However, it is somewhat unusual to expect such forms of animal life to remain dormant in air-dried soil for three years and then resume parasitic habits after this period if favorable conditions for plant growth are provided Nematodes, on the other hand, have this capacity.

SUMMARY

A study was made on the action of certain chemicals, commonly used as insecticides and nematocides, on the development of winter wheat mosaic. Samples of a specified quantity of virus-infested soil were subjected for seven days to the gases of five volatile liquids and two solids; besides, one contact insecticide was studied in this connection.

Calcium cyanide when used in the greatest amount and carbon disulphide, chloropicrin and methyl bromide at each of the three concentrations used completely controlled wheat mosaic. Ethylene dichloride reduced the incidence of the disease at the two larger dosages, but etyhl chloride gave no control. The fumes of naphthalene and rotenone dust, when mixed with the soil, also gave complete control of the disease.

The action of these chemicals was probably on the vector rather than on the virus.

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SOME LOCATIONS FOR FOSSIL PLANTS IN OHIO

WILBER STOUT,
Geological Survey of Ohio

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INTRODUCTION

The object of this paper is not an intrusion on the field of the botanist but is simply the listing of places favorable for the collecting of plant fossils in Ohio and the recording of the geology of such beds so that the botanist will know the position of the stratum in the geological column. The localities are definitely recorded (by number) and the place of contact is mapped on the topographic sheets (filed with the Botany Department, Ohio State University). The work of the geologists, as here defined, extends over a period of more than one hundred years (1836–1944) hence the actual exposure may now (1944) be hidden but the rock formations are still there. Diligent search may be necessary to uncover the fossil beds.

The tools for exploration should be: topographic map of the area, hand level, 6-foot ruler to determine position of the bed, a good geologist's hammer, pick and shovel, and, in some cases, a breast auger and a few sticks of dynamite. Coal mines usually yield some plant fossils, in the roof shales, in the bony partings, in the "mother coal" bands, and in the underclays. The treatment of the horizons is, in general, in ascending order, that is, from the Sharon coal of the Pottsville Series of the Pennsylvanian system to the Hundred sandstone of the Washington formation of the Permian system.

PENNSYLVANIAN SYSTEM

Throughout the geological ages the great period for plant species was during the time of the deposition of the thick mass, over 1,100 feet in Ohio, of sediments constituting the Pennsylvanian system. Then the coal beds, mainly of organic matter, were deposited, cycle after cycle, and on the average about 35 feet apart.

Some of these beds are quite thick over extensive areas and hence took great masses of vegetable matter to form them. The underclays, purified largely through the action of organic acids, bear much evidence of plant roots and stems. The shales overlying the coal beds are locally rich in plant remains, often in a fine state of preservation. However, the coal forming stages were closed frequently by subsidence, letting in the sea with the deposition of limestones and calcareous shales with a wide range of animal fossils.

POTTSVILLE SERIES

Pottsville time evidently opened with an abundance of plant species, as is indicated by the thickness and number of coal beds and by the numerous plant markings in the overlying shales. This series of rocks in Ohio is, on the average, about 256 feet in thickness and contains twelve recognized coal beds, some of which are of major importance. These rocks extend from Scioto County on the Ohio River to Trumbull and Mahoning Counties on the Ohio-Pennsylvania line.

SHARON COAL HORIZON

The Sharon coal is found chiefly in three fields:

(a) Jackson field, in Jackson, Pike and Scioto Counties.
(b) Massillon field, in Stark, Wayne, Summit and Portage Counties.
(c) Mahoning Valley field, in Trumbull and Mahoning Counties.

In general the roof shales of the Sharon coal contain plant fossils and locally they are very rich in well preserved material.

Reference: Geological Survey Ohio Vol. 1, Paleontology, Plant Fossils by J. S. Newberry, pages 359-385.

Location: See Akron, Kent, Massillon, Warren and Youngstown sheets for old mine locations.

The plant fossils were gathered largely from Coal Hill near Tallmadge, from Mineral Ridge south of Warren, and from the Massillon field near Massillon. Although the mining of coal is small at present in these areas, yet a few mines are found. Further, some outcrop exposures are available for collecting.

Reference: Second Annual Report on the Geological Survey of Ohio, 1838, page 60.

Location: A detached hill, one mile west of the center of Tallmadge, Summit County, overlies at least 500 acres of accessible coal. Kent topographic sheet.

"The coal (Sharon) is somewhat undulating, varies in thickness from two to five feet, and cokes well. The shale and sandstone roof contains an abundance of vegetable fossils."

Reference: Section 70, field notes, Jackson County, Stout.

Location: Shaft mine of the Jackson Iron and Steel Company, west of Jackson, in the southwest corner of Section 30, Lick Township, Jackson County. Jackson topographic sheet.

	Ft.	In.
Ore, *Lincoln*	1	0
Sandstone, flaggy	42	0
Shale, gray	5	0
Coal, *Anthony*	0	6
Clay, soft, *Sciotoville*	3	0
Covered	63	0
Top of shaft.		
Shales and covered	25	0
Shale, with plant fossils	5	0
Coal, *Sharon*	3	3
Shale, sandy	2	10
Conglomerate, *Sharon*	60	0

Many Sharon coal mines of the Jackson district yield plant fossils in the overlying shales. Some mines show flattened stems and trunks, a few of rather large size. As this is the oldest coal in Ohio these plants represent the life at the beginning of the great coal forming period, the Pennsylvanian system.

Reference: Section 91, field notes, Jackson County, Stout.
Location: Shaft mine of the Globe Iron Company, located one and one-fourth miles southeast of Jackson in the east central part of Section 28, Lick Township, Jackson County. Jackson topographic sheet.

		Ft.	In.
Sandstone		10	0
Ore, Kidney, *Upper Mercer*		0	6
Covered		77	0
Shales, parts covered		10	0
Coal blossom, *Vandusen*		0	4
Covered		28	0
Coal, *Bear Run*		0	8
Clay, siliceous		1	0
Shale, gray		1	0
Covered		20	0
Sandstone, massive, *Massillon*		10	0
Top of shaft.			
Shale and sandstone		100	0
Shale, gray, with many plant fossils		10	0
Coal, bony	*Sharon*	0	1
Coal, good	*Sharon*	3	3½
Coal, bony	*Sharon*	0	4

Reference: Geological Survey Ohio, Fourth Series, Bulletin 20, page 594.
Location: "Sharon conglomerate—In the sandy layers of the Sharon conglomerate in eastern Harrison and Madison townships, Scioto County, well preserved trunks and stems of Coal Measure plants were seen and in a few places observed even in the pebbly layers." "Sharon coal horizon—As would be expected, plant remains are common at this horizon, especially in the regions where the coal is well developed. Many root markings are present in the clays below the coal, while in the shales above the impressions of plant trunks and stems are common. The leaves are not usually well preserved."

SCIOTOVILLE CLAY HORIZON

The Sciotoville clay is widely distributed, but in patches across the State. The chief productive field is in eastern Scioto County. Small bodies of clay are also worked in Jackson, Vinton and Hocking Counties.

Reference: Geological Survey Ohio, Fourth Series, Bulletin 20, page 596.
Locality: largely Scioto County: "Sciotoville Clay Horizon—The clay contains impressions of roots of Coal Measure plants, but no evidence of animal life was found. The shales and shaly sandstone above the clay in many localities in Scioto and Jackson Counties contain fossil *Conostichus* and *Asterophycus* in large numbers. A few places for collecting are: the old clay mine on Daum Hill, in Section 33, Harrison Township, Scioto County; on the land of Dr. Keyes, in Section 28, Harrison Township; along the cut of the Baltimore and Ohio Southwestern Railroad, near Gephart; and on the point of the hill just north of the plant (abandoned) of the Buckeye Fire Brick and Clay Company at Scioto Furnace. At the last named locality worm tracks are also found in the shaly sandstone."

Reference: Section 1, field notes, Scioto County, Stout.
Location: Munn Hill, southwest Section 33, Harrison Township Scioto County. *Conostichus* and *Asterophycus* found in shales and shaly sandstone above the Sciotoville clay. Clay horizon marked by old strip mines near the top of the hill. Sciotoville topographic sheet.

	Ft.	In.
Pottsville formation:		
Shale and shaly sandstone, with plant fossils	20	0
Coal, *Anthony*	0	6
Clay, flint, many root impressions, *Sciotoville*	3	6
Shale and covered	38	0
Erosion interval:		
Flint, pebbles and ore, *Harrison*	2	0
Waverly formation:		
Shales and shaly sandstones.		

Such fossils are also present on the narrow ridge in the southeastern part of Section 32, along the ridge in southeastern Section 29, and along the main ridge in the southern part of Section 28, Harrison Township, Scioto County.

Reference: Section 55 L. field notes, Scioto County, Stout.
Location: Cut of Baltimore and Ohio Railroad, northeast of Gephart, in the east central part of Section 30, Bloom Township, Scioto County. Sciotoville topographic sheet.

		Ft.	In.
Shales, thin bedded, blue, with Conostichus in cut of railroad		27	0
Coal, dense, bright, good	*Anthony*	0	4
Shale, impure	*Anthony*	0	2
Coal, dense, bright, good	*Anthony*	0	7
Clay, flint and semiflint, good, with root impressions, *Sciotoville*		5	6
Conglomerate, *Sharon*		20	0

Reference: Section 246, field notes, Scioto County, Stout.
Location: Section at Scioto Furnace, on point of hill in southwestern Section 21, Bloom Township, Scioto County, Sciotoville topographic sheet.

	Ft.	In.
Sandstone, shaly	10	0
Shales, with thin sandstone and flag ore layers, sandstone layers with worm tracks	4	0
Covered	5	0
Shale with thin sandstone layers	6	0
Covered	16	0
Shales with thin sandstone layers, also Conostichus fossils	21	0
Coal smut, *Anthony*	0	2
Clay, flint, sandy, *Sciotoville*	10	0

Reference: Section 258, field notes, Jackson County, Stout.
Location: Up road one mile west of Riegel School, just south of crossroads, in the central part of Section 4, Hamilton Township, Jackson County. Oak Hill topographic sheet.
The Sciotoville clay very frequently, contains many root impressions, locally giving the name "Calico clay" to the material. At this place this condition prevails:

		Ft.	In.
Shales and covered		20	0
Sandstone, flaggy, red colored, very ferruginous, horizon of *Lincoln* ore		3	0
Shale, gray		3	0
Shales and covered		8	0
Sandstone, medium bedded		19	0
Covered		15	0
Sandstone		1	0
Coal, dense	*Huckleberry*	0	8
Shale, dark	*Huckleberry*	1	3
Coal, dense	*Huckleberry*	1	2

Clay, dark, sandy		2	0
Clay shales		5	0
Ore, siliceous, *Guinea Fowl*		1	6
Shale, gray		1	3
Coal blossom, Anthony		0	1
Clay, very siliceous, light, root marked	*Sciotoville*	4	6
Clay, very siliceous, light	*Sciotoville*	3	0
Clay, siliceous, with ore nodules	*Sciotoville*	1	0
Sandstone, irregularly bedded, red colored		5	8

GUINEA FOWL ORE HORIZON

The Guinea Fowl ore is local in distribution and is confined largely to Scioto, Jackson, and Vinton Counties. It was worked for iron smelting only in Scioto County. Locally the shale, sandstone, and iron ore at this horizon are sparingly fossiliferous.

Reference: Section 65, field notes, Scioto County, Stout.

Location: Record taken along the road, just east of the center of Section 10, Madison Township, Scioto County, on the property of Sampson Spriggs. Sciotoville topographic sheet.

	Ft.	In.
Sandstone, many plant fossils.	2	0
Ore, blocky, good, *Guinea Fowl.*	0	5
Sandstone, ferruginous	0	8
Shale and covered	10	0
Clay, good, light, plastic, *Sciotoville.*	2	0

QUAKERTOWN COAL HORIZON

The Quakertown coal is widely distributed across Ohio from Scioto County on the Ohio River to Mahoning County on the Ohio-Pennsylvania line. Locally it bears plant fossils, occasionally in abundance and well preserved.

Reference: Section 52, field notes, Scioto County, Stout, also Geological Survey Ohio, Fourth Series, Bulletin 20, pages 551 and 596.

Location: On land of Henry Moore, south of Frederick Creek, in the northeastern part of Section 20, Bloom Township, Scioto County. Sciotoville topographic sheet.

		Ft.	In.
Shale, with plant fossils		2	0
Shale, black, with thin coal bands.	*Quakertown*	0	4
Coal, solid block, good.	*Quakertown*	1	5
Shale and covered		31	0
Ore, *Guinea Fowl*		0	6
Shale		6	6
Coal, *Anthony*		0	2
Clay, flint and semi-flint. *Sciotoville.*		3	0

Reference: Geological Survey Ohio, Vol. 2, Paleontology. Description of Fossil Plants from Lower Carboniferous Strata, E. B. Andrews, pages 413–426.

Location: "Plants found in a thin band of bituminous shale located a little above the base of the Coal Measures, in Perry County, about two miles east of Rushville. This layer of shale is from 25 to 30 feet above the top of the Maxville limestone. The shale containing the plants I (Andrews) have never found except at one spot, where it is exposed in a ditch by the roadside, and all the plants were found within the limits of a few square yards." The probable location of this spot is in the west central part of Section 26, Reading Township, Perry County. The horizon is the Quakertown or possibly Bear Run coal. Thornville topographic sheet.

LINCOLN OR JACKSON SAND BLOCK ORE HORIZON

This ore is very uncertain in distribution and in character. The chief field is in southern Ohio. Locally it bears plant fossils, some well preserved.

Reference: Geological Survey Ohio. Fourth series, Bulletin 20, page 597.
Location: Worked in southeastern Section 16, Bloom Township, Scioto County. Sciotoville topographic sheet.
"Lincoln ore.—The deposits of Lincoln ore north of Scioto Furnace contain plant fossils."

Reference: Section 88, field notes, Jackson County, Stout.
Location: The largest mine of Jackson Sand Block ore was on the property of John W. Corn, in the northwestern part of Section 2, Scioto Township, Jackson County. Jackson topographic sheet.
In this area the Lincoln or Jackson Sand Block ore contains some plant fossils. Seeds and seed pods are present but not common. The deposits formerly worked were southwest of Jackson in southwestern Lick, southeastern Liberty, and northeastern Scioto Townships, Jackson County.

		Ft.	In.
Shale, blue		6	0
Ore, good	Jackson Sand Block	1	2
Shale, blue	Jackson Sand Block	0	11
Ore, solid block	Jackson Sand Block	5	10
Clay shale, sandy.			

At this place the ore lies 115 feet above the Sharon coal.

VANDUSEN COAL HORIZON

The Vandusen coal is irregularly but rather widely distributed. It is always thin, seldom reaching one foot in thickness. In southern Jackson County the overlying shales are rich in plant fossils, well preserved.

Reference: Section 266, field notes, Jackson County, Stout.
Location: Record taken along the stream on the Marion Vandusen property and along the road in the east central part of Section 1, Hamilton Township, Jackson County. Coal seen in bank of Little Scioto River. Oak Hill topographic sheet.

		Ft.	In.
Ore, *Upper Mercer*		0	6
Covered		37	0
Ore, Lower Mercer or *Little Red Block*		0	3
Covered		77	0
Shale, dark blue		7	0
Shale, light blue, with many plant fossils well preserved		2	0
Shale, bony	*Vandusen*	0	6
Coal, good	*Vandusen*	0	11

Reference: Section 285, field notes, Jackson County, Stout.
Location: Plant fossils are also abundant in the shales above the Vandusen coal along the stream in the south central part of Section 13, Scioto Township, Jackson County, on the property of W. T. Plummer and that of H. A. Wykle. Oak Hill topographic sheet.

	Ft.	In.
Ore, *Upper Mercer*	0	4
Covered	43	0
Sandstone and covered	20	0
Covered	14	0
Coal and bone shale, *Lower Mercer*	4	0
Covered	9	0
Shale, gray	11	0
Shale, blue, many plant fossils	7	0
Coal, *Vandusen*	0	11

Reference: Section 308, field notes, Jackson County, Stout.

Location: Record taken near the Grange Hall, east central Section 19, Franklin Township, Jackson County, seen along road on Four-mile Creek, near Portsmouth-Jackson Pike. Oak Hill topographic sheet.

	Ft.	In.
Shales and shaly sandstone	8	0
Shale, dark, with many plant markings.	1	0
Shale, coaly, *Vandusen* coal horizon	0	5
Clay, light, shaly	1	0
Sandstone	5	0

UPPER MERCER COAL HORIZON

The mineable deposits of Upper Mercer coal are confined largely to southern Ohio, in Jackson, Scioto, and Lawrence Counties. The roof shales frequently bear plant fossils and locally are rich in such material. The chief area for collecting is north of Jefferson Furnace in Jackson County.

Reference: Section 169, field notes, Jackson County, Stout.

Location: On the property of Stephen Jones in south central Section 8, Jefferson Township, Jackson County, the Upper Mercer coal is mined for local use. The overlying shale is rich in plant fossils. Oak Hill topographic sheet.

	Ft.	In.
Sandstone and shale	17	0
Shales	8	0
Clay and clay shales, light, *Brookville*	7	0
Sandstone	8	0
Covered	6	0
Sandstone, massive	18	0
Ore, *Upper Mercer.*	0	2
Shale and covered	8	10
Ore, *Sand Block.*	0	4
Shale, rich in plant fossils.	9	8
Coal, good, *Upper Mercer.*	1	10
Clay, light	2	0
Sandstone, massive	25	0

BEDFORD COAL HORIZON

In general, the Bedford coal is overlain by the Upper Mercer limestone, flint, or ore, all of marine origin. Locally, however, these are absent and shale is found on the horizon. In a few places this shale bears plant fossils.

Reference: Section 63, field notes, Vinton County, Stout.

Location: Record taken along the road in the south central part of Section 17, Elk Township, Vinton County. Zaleski topographic sheet.

		Ft.	In.
Sandstone, soft		15	0
Coal, good	*Winters*	0	6
Clay, impure	*Winters*	0	3
Coal, good	*Winters*	0	7
Clay, dark	*Winters*	0	5
Coal, good	*Winters*	1	2
Covered, with flint		7	0
Top of road on ridge.			
Soil		4	6
Shale, gray		6	0
Shale, badly weathered, fossiliferous, *Putnam Hill*		0	6
Coal blossom, *Brookville* or *Newland*		4	0

	Ft.	In.
Clay, light, plastic	4	0
Shale, gray	13	0
Shale, dark, plant fossils, Bedford coal horizon	1	0
Clay, dark, impure	2	6
Shale, siliceous	7	0
Sandstone, soft, part shaly	6	0
Clay shale, siliceous, *Upper Mercer* coal horizon	2	0
Covered	19	0
Limestone, shaly, part covered } *Lower Mercer*	5	0
Limestone, hard, blue } *Lower Mercer*	0	7

TIONESTA COAL HORIZON

The Tionesta coal is widely distributed but usually thin and shaly. Its position is close below the Brookville clay. Where shale intervenes between the Tionesta coal and the Brookville clay this shale often bears plant fossils, locally in abundance.

Reference: Section 16, field notes, Muskingum County, Lamborn.
Location: Section taken at the old stone quarry near the plant of the Zanesville Stoneware Company in Putnam, a suburb of Zanesville, Muskingum County. Zanesville topographic sheet.

	Ft.	In.
Limestone, *Putnam Hill*	2	0
Clay and covered, *Brookville*	3	0
Shales, sandy	8	0
Shales, gray to dark, plant fossils abundant	9	6
Coal, *Tionesta*	1	10
Clay, siliceous	1	2
Sandstone, shaly	1	0
Sandstone, *Homewood*	21	0

Reference: Second Annual Report on the Geological Survey of Ohio, 1838, page 101, J. W. Foster.
Location: At Zanesville.
"Few places in the world, perhaps, afford plant fossils in such abundance and perfection as the mines about Zanesville. Many of the plates in the splendid work, "Histoire des Vegetaux Fossile," by M. Adolphe Brongniart, were figured from specimens furnished him by the late Ebenezer Granger, Esquire, or from drawings sent by W. A. Adams, Esquire, all of which were procured near Zanesville. Among that collection were the *Neuropteris Grangeri*, named in honor of the first gentleman; and the *Poacites lanceolata*, vegetables which have been found only at Zanesville."

Further, for the Tionesta horizon on Putnam Hill, near Zanesville see Observations on the Bituminous Coal deposit of the valley of the Ohio, and the accompanying rock strata; with notices on the fossil Organic remains and the relics of Vegetable and Animal bodies, illustrated by a Geological map, by numerous drawings of plants and shells, and by views of interesting scenery; by Dr. S. P. Hildreth, of Marietta, Ohio, the American Journal of Science, and Arts, Vol. XXIX, January, 1836, pages 80–38.

ALLEGHENY SERIES

In Ohio the Allegheny series has a thickness of close to 212 feet and in the section bears thirteen coal beds, some of which are exceptionally well developed. Plant fossils are common in many localities but only a few of the richer fields will be noted here.

CLARION COAL HORIZON

In most of the field the Clarion coal is overlain by the Vanport limestone of marine derivation. Locally this limestone is replaced by shale which occasionally bears plant fossils.

Reference: Section 53, field notes, Vinton County, Stout.
Location: On the Orval Lewis proprety, just east of Prattsville, in north central Section 26, Madison Township, Vinton County. Wilkesville topographic sheet.

	Ft.	In.
Sandstone, soft, friable	10	0
Shale, gray	12	0
Coal, shaly, *Scrub Grass*	1	5
Shale, black, carbonaceous, plant fossils	4	2
Coal, with partings, *Clarion*	4	0

Reference: Section 93, field notes, Columbiana County, Lamborn.
Location: Section along the paved road, west side of California Hollow, just north of the center of Section 24, Liverpool Township, Columbiana County. Wellsville topographic sheet.

	Ft.	In
Sandstone, gray, siliceous	20	0
Coal, on outcrop, *Rogers, Lower Freeport*	2	0
Clay, siliceous	2	0
Shale, gray, siliceous	25	0
Sandstone and covered	50	0
Coal blossom, *Lower Kittanning, No. 5*	2	0
Clay and covered	5	0
Sandstone, shale and covered	83	0
Sandstone, heavy ledge	2	0
Shale, gray, siliceous	1	8
Sandstone	1	1
Shale, gray, siliceous, ferruginous	1	3
Shale, dark, carbonaceous, with plant fossils	0	5
Clay, gray, plastic, a little siliceous } *Clarion*	0	9
Clay, gray, very siliceous at base } *Clarion*	1	5
Sandstone	20	0

LOWER KITTANNING COAL HORIZON

The Lower Kittanning coal is very persistent across the State, seldom being absent from the section. The overlying shales frequently yield some plant fossils but locally offer good collecting.

Reference: Section 179, Geological Survey Ohio. Report of Progress, 1870, page 179, Gallia County.
Location: Record taken in Section 7, Huntington Township, Gallia County, about 1½ miles east of Keystone Furnace. Wilkesville topographic sheet.

	Ft.	In.
Clay shale, blue, rich in coal plants	6	0
Coal, upper 8 inches shaly, *Lower Kittanning*	4	0
Covered	50	0
Ore, *Ferriferous*	1	0
Limestone, Vanport	4	0

This coal is exposed along the valley in the southwestern part of Section 7, at an elevation close to 700 feet.

Reference: Section 150, field notes, Vinton County, Stout.
Location: Section taken along the road to the ridge in the northeastern part of Section 22, Elk Township, Vinton County. (See Bulletin 31, Geol. Survey Ohio, page 294.) Zaleski topographic sheet.

		Ft.	In.
Shale, gray		5	0
Coal, bony	*Middle Kittanning* mine of Jacob Morgan, elevation 900 feet	0	6
Shale, dark		0	3
Coal, good		2	8
Shale, impure		0	1
Coal, good		0	4
Clay shale, sandstone and covered		38	0
Shale, gray, with well preserved plant fossils		5	0
Clay shale, dark, with papery coal		1	3
Coal, good	*Lower Kittanning*	0	4
Clay shale		0	4
Coal, hard, bony		2	5
Clay shale		0	4
Coal, poor		0	6
Covered		6	0
Sandstone		25	0
Covered, *Vanport* limestone in interval		6	0
Coal, rough	*Clarion*	1	0
Clay, impure		0	6
Coal, good		1	7
Clay shale		0	1
Coal, good		1	1

STRASBURG COAL HORIZON

In Ohio the Strasburg coal is only locally well defined, best in the Strasburg area of Tuscarawas County. However, the horizon may be traced over a wide area.

Reference: Section 34, field notes, Muskingum County, Stout.

Location: At the pit of the Burton-Townsend Brick Company, No. 2 plant, east of Zanesville, Muskingum County. Philo topographic sheet.

		Ft.	In.
Sand, used for molding sand		20	0
Shale, gray, used for brick		40	0
Coal, bony	*Middle Kittanning*	0	7
Coal, good		2	2
Shale, dark		0	1
Coal, good		0	10
Clay, plastic, shaly		5	6
Sandstone, ferruginous, shaly		2	6
Shale, with very fine plant fossils well preserved		4	6
Coal, hard, bony, *Strasburg*		0	2
Clay, plastic		5	0
Clay, part flint, with limestone nodules		7	0
Coal smut, *Lower Kittanning*		0	1
Clay, light, plastic		7	0
Clay, very siliceous		7	0
Sandstone.			

In the following section the shale bearing plant fossils is not well identified but evidently belongs to the Strasburg coal horizon.

Reference: Section 77, Thesis, Ohio State University, 1929, Theodore Ralph Meyers, The Geology of Jefferson and Bedford Townships, Coshocton County, page 77.

Location: Coal mine one-fourth mile northeast of McCurty School in the southeastern part of Section 19, Bedford Township, Coshocton County. Brinkhaven topographic sheet.

		Ft.	In.
Sandstone, massive, yellowish-brown, *Lower Freeport*		25	0
Shale, blue-gray		1	6
Coal, shaly	*Middle Kittanning*	0	7
Shale, dark	*Middle Kittanning*	0	2½
Coal, good	*Middle Kittanning*	2	7
Clay shale, gray	*Middle Kittanning*	0	½
Coal, fair	*Middle Kittanning*	0	3
Clay, plastic, light colored		0	4
Shale, siliceous, with plant fossils		1	6

SNOW FORK ORE HORIZON

Locally across the State and from 5 to 15 feet below the Middle Kittanning coal a limestone or an iron ore makes its appearance. In eastern Ohio in Columbiana and Mahoning Counties the limestone, the common phase, is known as the Salem and in the Hocking Valley of Athens and Hocking Counties the iron ore, there important for iron smelting, was known as the Snow Fork.

Reference: Record 600, Second Annual Report of the Geological Survey of Ohio, 1838, pp. 143–4. C. Briggs, Jr. Also Geol. Survey Ohio, Volume 111, pages 866 and 906–907, Andrews.

Location: Chief field on Snow Fork east of Buchtel, in Section 6, York Township, Athens County.

"The most continuous, and probably the most valuable, deposits of iron ore in this county (Athens), is a few feet below the Nelsonville (Middle Kittanning) coal. This is a very heavy, compact ore, of a bluish color, and varies in thickness, from 6 to 10 inches. It contains impressions of ferns and other extinct vegetation. It is well disclosed at Whittimore's (one mile east of Buchtel) on the Snow Fork of Monday Creek, resting on a bed of shale, which disintegrates into a yellowish, ochrey clay. Split in the line of cleavage, it often reveals beautiful impressions of vegetable."—Briggs.

"On lower Monday Creek, and on Snow Fork, the ore is in flat discs, which contain coal plants in a state of beautiful preservation. The ore is recognized by all familiar with the geology of this district (Hocking Valley) from its relation to Coal No. VI, (Middle Kittanning) with which it is closely associated, underlying it at an interval of two to ten feet. It is a very compact and close-grained, blue carbonate, lying in large blocks and kidneys, in the clays that support the coal. It is also characterized from the Hocking Valley to the Ohio River by holding beautifully preserved coal plants. Leaflets of ferns, bits of bark, and branches are found throughout its substance, often in an exquisite state of preservation. Insect remains are to be expected here. The ore was first recognized with all of these peculiarities by the geologists of the First Survey (1838). The locality at which they found it is one of the best known today (1878), viz., the Whitmore farm on Snow Fork, a mile east of Bessemer (Buchtel). It is designated in the section as the Snow Fork ore."—Andrews.

MIDDLE KITTANNING COAL HORIZON

The Middle Kittanning is one of the great coal beds of Ohio. It is persistent and maintains good thickness and quality across the State. In large areas in eastern and central Ohio it is overlain by shales and limestones with marine fossils. However, in the Hocking Valley around New Straitsville, Shawnee, Hemlock, and Buckingham the overlying shales provide one of the best collecting grounds for plant fossils in Ohio. Other areas in southern Ohio yield some material of fair quality.

Reference: Section 6, field notes, Jackson County, Stout.

Location: Record taken in the northeastern part of Section 4, south, Madison Township, Jackson County, on the Thomas Davis property just west of Sardis Church. Oak Hill topographic sheet.

		Ft.	In.
Shale, siliceous		5	0
Shale, very fossiliferous, plant types.		2	0
Shale, "draw slate"		0	2
Coal, good	Middle Kittanning	1	11
Clay and bony coal	Middle Kittanning	0	2
Clay, siliceous		4	0

Reference: Section 841, Geological Survey Ohio, Report of Progress, 1869, page 100; Ibid, Volume 111, pages 841–842.

Location: "On the farm of Benjamin Sanders, Monroe Township, Perry County, on the west branch of Sunday Creek the coal (Middle Kittanning) measures 11 feet." This section was taken a little below Hemlock. New Lexington topographic sheet.

		Ft.	In.
Soil		..	..
Shale, with coal plants		..	..
Coal	Middle Kittanning	1	1
Slaty streak	Middle Kittanning	0	3
Coal	Middle Kittanning	5	9
Clay parting	Middle Kittanning	0	1½
Coal	Middle Kittanning	3	0
Fire clay		.	.

Reference: Geological Survey Ohio, Report of Progress 1869, page 99.

Location: "At Gaver's mill, and on the adjacent land at L. M. McDonald, Esquire, near the Coal Dale, P. O., Salt Lick Township, Perry County, the seam (Middle Kittanning) measures 6 feet, 2 inches. Location north of New Straitsville, not definitely placed. New Lexington topographic sheet.

		Ft.	In.
Sandstone, heavy		40	0
Shale, blue, rich in coal plants		4	6
Coal, slaty	Middle Kittanning	0	2
Coal, good	Middle Kittanning	0	8
Shale, with pyrite	Middle Kittanning	1	0
Coal, good	Middle Kittanning	2	4
Clay, black	Middle Kittanning	0	0½
Coal, good	Middle Kittanning	0	10
Clay, black	Middle Kittanning	0	1
Coal, good	Middle Kittanning	1	10½

"Here there is a good slate roof, very rich in plant fossils."

CONEMAUGH SERIES

The last invasion of the ocean during Pennsylvanian time occurred at the horizon of the Skelley limestone about midway in the Conemaugh series. Above that member the strata are entirely fresh water and below it both marine and fresh water. This group of rocks in Ohio averages about 400 feet in thickness. It bears eleven named coal beds but all of them are thin, some mere soot streaks. However, they afford good collecting for the paleo-botanist. The outstanding horizons are the Mahoning, Mason, and Harlem, each of which will yield much good material.

MAHONING COAL HORIZON

The Mahoning coal near the base of the Conemaugh group of strata is one of the outstanding horizons in Ohio for plant fossils. The coal is of importance only in the eastern part of the State. A few of the better places will be listed.

Reference: Section 318, field notes, Gallia County, Stout.

Location: Taken along road, from the valley to the ridge crest in Section 34, Morgan Township, Gallia County. Bidwell topographic sheet.

		Ft.	In.
Shale, gray		11	0
Clay shales, red		7	0
Limestone, very fossilferous, *Ames*		2	0
Shale, gray		18	0
Clay shale, red		15	0
Shale, gray		9	0
Clay shale, red		10	0
Sandstone, shaly		6	0
Covered		16	0
Limestone, *Cambridge*		2	0
Coal, *Wilgus*		1	0
Clay, light		1	0
Shales and covered		7	4
Sandstone, shaly, ferruginous		0	8
Shale, siliceous		9	0
Covered		6	0
Limestone, shaly	*Brush Creek*	1	0
Shale, calcareous	*Brush Creek*	6	0
Limestone, irregular	*Brush Creek*	1	0
Sandstone, calcareous, ripple marked		33	0
Coal, *Mason*		1	0
Shale, blue		15	0
Shale, very rich in plant fossils		4	0
Coal, good, *Mahoning*, on John Spires property		0	10
Clay, light		3	0
Clay, mottled		5	0
Shales, gray, calcareous		6	0
Clay shales, light, parts covered		10	0
Sandstone, massive, *Mahoning*		10	0
Coal, *Upper Freeport*, below sandstone but not seen			

Reference: Section 1 C, Geological Survey Ohio, Fourth Series, Bulletin 17, Condit. Page 231.

Location: Shale pit in southeast Section 7, Center Township, Carroll County. Carrollton topographic sheet.

"The Deckman-Duty Brick Company, Carrollton.

"This brick plant is situated on the north side of the Wheeling and Lake Erie Railroad, about one mile southwest of Carrollton.

"At the hill top is a coarse-grained sandstone, 12 feet thick, which is stripped. The underlying shale, 54 feet thick, is bluish-gray in the unweathered portion, and near the surface shows greenish or rusty-brown tints. Irregular carbonaceous streaks, having abundant plant impressions, are plentiful in the lower portion, together with occasional carbonate concretions. The lower portion of the pit exposing the Mahoning coal ('Strip Vein' of Salineville) with a thickness of about 1 foot, and the Upper Freeport coal, lying 40 feet lower, is mined in a neighboring hollow."

MASON COAL

As a coal bed the Mason is of little importance in Ohio. The usual mark is a few inches of shaly coal or a mere soot streak. Locally, however, it offers good collecting for fossil plants.

Reference: Section 350, field notes, Gallia County, Stout.

Location: Section taken along the road in the northwest corner of Section 34, Raccoon Township, Gallia County, Bidwell topographic sheet.

		Ft.	In.
Shales, gray		8	0
Shale, hard, bony		0	4
Shale, many plant fossils		2	8
Coal, bony	*Mason*	0	5
Coal, good	*Mason*	1	2

Reference: Section 1045, Geological Survey Ohio, Fourth Series, Bulletin 35, page 125, Lamborn.

Location: Section taken at the Quarry of the General Stone Company, above the river road, in the northern part of Section 25, Island Creek Township, Jefferson County. Steubenville topographic sheet.

	Ft.	In.
Shale, arenaceous, estimated	40	0
Clay, bluish-gray, with limestone nodules	4	0
Clay shale, red	20	0
Coal blossom, *Wilgus*	0	1
Clay, gray, arenaceous	6	2
Clay shale, red, with ore nodules	18	0
Sandstone, massive, *Buffalo*	35	0
Covered	32	0
Shale, gray, calcareous	8	0
Clay, dark, shaly	1	4
Clay, grayish-brown, arenaceous	5	4
Shale, calcareous	18	8
Shale, dark, with plant impressions	1	2
Coal, shaly, *Mason*	0	3
Clay, gray, plastic	8	0

Reference: Section 964, Geological Survey Ohio, Fourth Series, Bulletin 35, pages 25 and 26, Lamborn.

Location: Section secured along Croxton Run, in the central part of Section 32, east, Knox Township, Jefferson County. Steubenville topographic sheet.

Conemaugh Series:		Ft.	In.
Limestone, greenish, fossiliferous, *Ames*		1	9
Shale, gray, arenaceous		8	0
Clay shale, red, *Round Knob*		28	2
Clay, shaly, dark, *Barton*		10	4
Clay, with nodules of limestone	*Ewing*	2	6
Limestone, nodular, fossiliferous	*Ewing*	1	4
Sandstone, shaly, *Cow Run*		28	6
Shale, arenaceous		2	0
Shale, black, with thin coal bands		2	0
Shale and covered		46	0
Limestone, blue, arenaceous, fossiliferous, *Cambridge*		0	11
Clay shale, blue to yellow in color		14	4
Shale, black, with shaly coal, *Wilgus*		1	10
Clay, dark, arenaceous		3	0
Clay shale		28	10
Limestone, black, fossiliferous, *Brush Creek*		1	3
Shale, dark, fissile		1	10
Shale, bony		1	2
Shale, black, with many plant impressions		4	6
Coal, bony, *Mason*		0	8
Clay, dark, with iron ore nodules		5	0

Reference: Section 1,008, Geological Survey Ohio, Fourth Series, Bulletin 35, pages 108–109, Lamborn.

Location: Record taken in the south central part of Section 34, Ross Township, Jefferson County. Salineville topographic sheet.

	Ft.	In.
Sandstone and arenaceous shale	26	0
Shale, dark, fossiliferous, *Brush Creek*	17	2
Shale, dark, with many plant fossils	3	0
Clay and covered, *Mason* horizon	14	10
Limestone, impure, ferruginous	1	2
Clay, with limestone nodules	15	8
Shale, gray to pink	28	4
Coal blossom, *Mahoning*	2	6
Clay, gray, plastic	2	0
Covered	9	4
Shale, gray, arenaceous	25	10
Shale, black, and shaly coal. *Upper Freeport*	0	6
Shale and covered	29	6
Coal, not entire thickness, *Lower Freeport*	2	0

Reference: Section 912, Geological Survey Ohio, Fourth Series, Bulletin 35, pages 22 and 23, Lamborn.

Location: Record taken in the ravine and along the road in the south central part of Section 12, Brush Creek Township, Jefferson County. Salineville topographic sheet.

Conemaugh Series:		Ft.	In.
Sandstone, thin bedded, *Cow Run*		40	0
Clay, blue, arenaceous		2	2
Clay, yellow, *Anderson* horizon		3	0
Shale, arenaceous		1	2
Sandstone, shaly		4	7
Shale, drab-colored, arenaceous		16	1
Limestone, bluish	*Cambridge*	1	2
Shale, bluish, fossiliferous	*Cambridge*	2	2
Shale, with thin coal bands, *Wilgus*		0	1
Clay, gray		5	0
Covered		5	4
Shale, bluish-gray, arenaceous		30	0
Shale, black, with iron ore nodules	*Upper Brush Creek*	5	4
Shale, black, fossiliferous	*Upper Brush Creek*	5	0
Limestone, black	*Upper Brush Creek*	1	2
Shale, black, micaceous	*Upper Brush Creek*	4	0
Clay shale, dark, fossiliferous	*Upper Brush Creek*	7	8
Coal, bony, *Brush Creek*		0	9
Clay, bluish-gray, arenaceous		6	8
Shale, bluish-gray, arenaceous		12	10
Shale, sandy, fossiliferous	*Lower Brush Creek*	0	3
Limestone, black, ferruginous	*Lower Brush Creek*	0	3
Shale, black	*Lower Brush Creek*	0	10
Shale, black, ferruginous, fossiliferous	*Lower Brush Creek*	0	2
Shale, black, sparingly fossiliferous	*Lower Brush Creek*	2	9
Shale, black, very fossiliferous	*Lower Brush Creek*	2	2
Shale, gray, arenaceous		12	2
Shale, black, with plant impressions, *Mason* coal horizon		0	8
Clay, bluish-gray, arenaceous		4	8
Sandstone, heavy bedded, *Upper Mahoning*		9	5

		Ft.	In.
Clay, bluish-gray, arenaceous		5	0
Covered		15	8
Sandstone, cross-bedded, *Lower Mahoning*		44	4
Allegheny Series:			
Shale, black, with thin coal bands, *Upper Freeport*		0	7
Clay, bluish-gray, arenaceous		4	0
Sandstone		1	0
Clay, ferruginous, arenaceous		2	6
Clay shale, blue		10	6
Sandstone, heavy bedded	*Upper Freeport*	5	0
Sandstone, platy	*Upper Freeport*	31	0

Reference: Section 907, Geological Survey Ohio, Fourth Series, Bulletin 35, page 119, Lamborn.

Location: An excellent exposure of the Brush Creek beds occurs in the southern part of Section 13, Brush Creek Township, Jefferson County. Salineville topographic sheet.

		Ft.	In.
Limestone	*Cambridge*	1	2
Shale, blue, fossiliferous	*Cambridge*	2	2
Shale, with coal bands, *Wilgus*		0	1
Clay, bluish		5	0
Covered		5	4
Shale, bluish gray, arenaceous		30	0
Shale, black, carbonaceous, with ore nodules		5	4
Shale, black, arenaceous, fossiliferous		5	4
Limestone, black		1	2
Shale, black, micaceous		4	0
Shale, dark, fossiliferous		7	8
Coal, bony, *Brush Creek*		0	9
Clay, bluish-gray, arenaceous		6	8
Shale, bluish-gray		12	10
Sandstone, dark, fossiliferous	*Lower Brush Creek*	0	3
Limestone, black, ferruginous	*Lower Brush Creek*	0	3
Shale, black	*Lower Brush Creek*	0	10
Shale, black, fossiliferous	*Lower Brush Creek*	5	5
Shale, gray, arenaceous		12	2
Shale, black, with plant impressions		0	8
Clay, bluish-gray, *Mason*		4	8

BARTON COAL HORIZON

Throughout most of the field in Ohio, the Barton coal is overlain by sandstones and shales with little or no evidence of either plant or animal life. The coal is poorly developed and very patchy in extent.

Reference: Section 48, field notes, Muskingum County, Lamborn.

Location: Section along north and south road in the southeastern part of Section 14, Union Township, Muskingum County. Philo topographic sheet.

	Ft.	In.
Sandstone, shaly	5	0
Shale, gray, sandy	10	0
Coal blossom, *Pittsburgh*	1	0
Clay shales and covered with lumps of limestone	2	0
Shales and covered	31	0
Shales, gray, sandy	36	0
Covered	10	0

	Ft.	In.
Shales, gray, sandy	44	0
Limestone, *Ames*	0	10
Shales, gray, sandy	21	0
Covered	10	0
Shales, with layers of shaly sandstone	5	0
Shales, rather siliceous	5	0
Covered	10	0
Shale, bony, black, fissile, plant fossils numerous, Barton coal horizon	0	10
Covered	0	6
Clay, gray, rather plastic	4	6

HARLEM COAL HORIZON

The Harlem coal, lying about the middle of the Conemaugh series, is the highest coal of any importance in this group of rocks. It is easily placed as it lies not far below the Ames limestone.

Reference: Section 151, field notes, Muskingum County, Stout.

Location: Record taken along the deep ravine in the east central part of Section 28 and the southwestern corner of Section 27, Bluerock Township, Muskingum County. Philo topographic sheet.

		Ft	In.
Shales, grayish yellow		1	0
Clay, limestone and covered		30	0
Shales, red, part covered, "Big Reds"		83	0
Sandstone, shaly		3	0
Clay shale, red, part covered		6	0
Limestone, ferruginous, fossiliferous, *Skelley*		0	4
Clay shales, red, part covered		22	8
Sandstone, calcareous, fossiliferous, *Gaysport*		1	0
Shales, gray		21	0
Limestone, *Ames*		1	7
Sandstone, shaly		2	0
Shale, siliceous, blue		26	0
Shale, dark, with thin bone bands, plant fossils abundant		1	0
Coal, bony	*Harlem*	0	6
Shale, dark	*Harlem*	0	5
Coal, good	*Harlem*	0	10
Clay, siliceous		2	0
Sandstone, shaly		2	0
Shale, gray		4	0
Coal	*Barton*	0	1
Shale	*Barton*	0	3
Coal	*Barton*	0	2
Clay shales		2	0
Sandstone, shaly		3	0
Shales, gray		8	0
Shales, black, with thin coal bands		2	0
Clay, very siliceous		1	6
Sandstone, with ore nodules		3	0

Reference: Section 1,134, Geological Survey Ohio, Fourth Series, Bulletin 35, page 198, Lamborn.

Location: The different members of the Pennsylvanian system from the Wilgus coal horizon to the Pittsburgh sandstone are shown along the tributary of Wells Run which heads near

Altamont Park in Section 28, Steubenville Township, Jefferson County, where the following section was measured. Steubenville topographic sheet.

	Ft.	In.
Sandstone, coarse, friable, *Pittsburgh*	24	0
Shale, gray, arenaceous	2	6
Coal blossom, *Pittsburgh*	3	0
Shale and covered	20	8
Clay, light, plastic	5	0
Shale, gray, arenaceous	51	8
Clay, calcareous	5	0
Limestone, light, *Clarksburg*	0	8
Clay, greenish-gray	2	0
Shale, calcareous, arenaceous	3	2
Shale, mottled	21	0
Shale and covered	25	10
Sandstone, *Morgantown*	27	0
Limestone, *Ames*	1	0
Shale and covered	23	10
Shale, black, with plant impressions	0	2
Coal, *Harlem*	1	6
Clay and covered	5	0
Sandstone, shale and covered	51	6
Shale, gray, arenaceous	20	0
Shale, with nodules of very ferruginous, calcareous, fossiliferous limestone, *Cambridge*	2	0
Coal smut, *Wilgus*	0	1
Clay, red to green	10	0

UPPER PART OF THE CONEMAUGH SERIES

In Ohio the interval from the Ames limestone to the Pittsburgh coal varies from 155 feet in Meigs County to 220 feet in Jefferson County. In general the formations in this section are extremely variable and locally wanting. The replacement may be 50 to 100 feet of clay shales, red in color and soft and structureless in character. These are known collectively to the geologist and driller as the "Big Reds." Such deposits in some areas appear to yield silicified wood and in others they contain many nodules of hematite, a few of which will yield well preserved plant remains.

SILICIFIED WOOD

Silicified wood in the red shales above the Ames limestone is abundant along the streams in Morgan Township, Gallia County.

"Near the head of Middle Branch of Shade River, in Section 1, Athens Township, Athens County, many specimens of silicified wood were seen in the bed of the creek, and many fine museum specimens have been taken from this locality. No blocks were seen in place in the hills, but it is probable that they have weathered out from shales lying a little higher [?] than the Pittsburgh coal."[1]

"Specimens of silicified wood are common in the hills of this region, (northwestern Homer Township, Morgan County) but none was seen in place. Loose blocks were found well up in the hills, and it is probable that they have weathered from shale lying a little above the Ames limestone."[2]

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[1]Geological Survey Ohio, Fourth Series, Bulletin 17, pages 119–120.
[2]Geological Survey Ohio, Fourth Series, Bulletin 17, page 140.

HEMATITE NODULES

Hematite can be found in some quantity in most of the streams in eastern Athens, eastern Perry, and western Morgan Counties. In some areas there are only a few scattered nodules; in others it is so thick that from one to two pounds may be picked from a square foot of surface. Some favorable places are: on the headwaters of Bryson Run, Section 36, Ames Township, Athens County; another is near Sayre in Bearfield Township, Perry County; and near Ringgold in Union Township, Morgan County. Similar deposits are found in eastern Lawrence and western Gallia Counties. Only a few of the nodules contain plant fossils. The plant fragments, however, are exceptionally well preserved.

MONONGAHELA SERIES

The Monongahela series, averaging about 245 feet in thickness, is made up largely of fresh-water limestones, calcareous shales, and sandstones. It contains seven coal beds some of which, Pittsburgh, Pomeroy, and Meigs Creek, are of great economic importance. The period was thus of organic origin and in some of the strata much evidence of the plant life prevails. Only a few of the better localities will be considered.

PITTSBURGH COAL HORIZON

In Ohio the Pittsburgh is a well marked horizon from Jefferson County on the north to Lawrence County on the south. The chief productive fields are the Eastern Ohio field in Jefferson, Harrison, Belmont, Monroe, and Guernsey Counties, the Federal Creek field in Athens and Morgan Counties, and the Swan Creek field in Gallia County. The roof shales in many mines bear some plant fossils.

Reference: Section 810, field notes, Athens County, Stout.

Location: Up the Marietta road at the Sharpsburg Hill, northeast Section 29, Berne Township, Athens County. Chesterhill topographic sheet.

	Ft.	In.
Sandstone, shaly.	2	0
Shale, siliceous, gray.	1	6
Coal, shaly, *Little Waynesburg*.	0	2
Clay, calcareous, grainy, gray to pink, parts marly.	10	9
Sandstone and shale, gray.	22	1
Limestone, nodular, pinkish.	0	8
Shale, pink, calcareous, parts gray..	22	1
Sandstone, shaly, gray...	2	0
Shale, pink, sandy.....	2	0
Coal smut, *Uniontown*....	0	1/16
Shale, pink to gray, calcareous, parts marly......	21	9
Shale and shaly sandstone.....	10	0
Shale, pink....	2	6
Coal smut, (*Arnoldsburg?*).....	0	6¼
Shales, calcareous....	10	5
Limestones and calcareous shales, *Arnoldsburg-Benwood*.....	48	0
Sandstone, massive, irregular, *Upper Sewickley*....	6	2
Shale, gray, siliceous.....	3	4
Coal smut, *Meigs Creek*....	0	0½
Shale, calcareous, blue to buff..	8	8
Shale, gray, parts very sandy..........	9	4
Clay, dark, smutty, *Fishpot* coal horizon..	0	2
Clay shale, dark........	1	0
Limestone, thin to massive, with thin shale partings.	7	0
Shale, pink, marly...	19	6
Limestone, sandy, yellowish......	1	10

		Ft.	In.
Shale, calcareous, gray to green to pink, marly with thin limestone layers		22	2
Shale and shaly sandstone		15	4
Shale, with plant fossils, roof of coal		1	0
Coal, good	*Pittsburgh,* mine of Eckard and Day, elevation 915 feet	5	4
Clay, soft, gray		0	11
Coal, good		3	9

Reference: Section 812, field notes, Athens County, Stout.

Location: Mine of L. E. Harris on the G. W. Selby land, northeast Section 30, Berne Township, Athens County. Chesterhill topographic sheet.

		Ft.	In.
Sandstone, massive, *Upper Pittsburgh*		20	0
Shale, dark, with plant fossils		1	5
Coal, with thin partings	*Pittsburgh*	3	0
Shale, with pyrite		0	0¼
Coal, good		0	1
Shale, hard, bony		0	11
Coal, good		0	4½
Clay, gray, soft		1	2½
Coal, good		3	9

Throughout most of the Federal Creek field the roof of the Pittsburgh coal yields plant fossils in fair abundance and with good detail.

Reference: Section 299, Geological Survey Ohio, Volume 1, page 298.

Location: In Section 34, Homer Township, Morgan County, on land of Mr. Bishop, the following section was taken (coal near top of high knob). New Lexington topographic sheet.

		Ft.	In.
Limestone, buff		1	0
Covered		27	0
Coal	*Pittsburgh*	3	0
Clay, with coal plants		1	0
Coal		4	0
Covered		142	0
Limestone, *Ames*		2	6

Reference: Section 298, Geological Survey Ohio, Volume 1, page 298.

Location: The following section of the (Pittsburgh) coal was taken on the land of J. Stinchcomb, Section 29, Homer Township, Morgan County. (This coal lies close to the top of the high ridge). New Lexington topographic sheet.

		Ft.	In.
Limestone, buff		1	0
Covered		12	0
Sandstone, *Upper Pittsburgh*		6	0
Shale, with coal plants		10	0
Coal	*Pittsburgh*	4	2
Clay		1	0
Coal		4	0
Covered		143	0
Limestone, *Ames*		2	0

Reference: Section 18, Washington County, Thesis, 1936, John C. Frye, State University, Iowa.

Location: On Cat Creek, about one mile southwest of the Noble-Washington County line, north of the stream, in the northeastern part of Adams Township, Washington County, the following rocks were exposed. Macksburg topographic sheet.

	Feet
Coal, *Meigs Creek*	2.0
Shale, gray, carbonaceous	4.0
Covered	35.4
Limestone, gray	0.8
Sandstone, fine grained, gray	3 5
Shale, calcareous, gray, fissile	3.8
Limestone, gray	0.2
Shale, calcareous	1.0
Shale and limestone, gray	3.5
Shale and covered	2.6
Shale, calcareous, gray, black and red	1.5
Sandstone, gray, fine grained	19.0
Covered	5.5
Shale, gray, calcareous	0 9
Shale, carbonaceous	0.08
Shale, very calcareous. The following plants collected: Pecopteris, several species; Neuropteris; Odontopteris; Equistides?.	2.1
Shale and covered	8.0
Coal, *Pittsburgh*	0.2
Limestone, black, shaly	0 9

Base of section in Cat Run at an elevation of 780 feet.

REDSTONE OR POMEROY COAL HORIZON

The Redstone or Pomeroy coal is widely distributed in Ohio but the field of economic importance is confined to southern Meigs and eastern Gallia Counties. In many localities the roof shales of this coal contain plant fossils in a fair state of preservation.

Reference: First Annual Report on the Geological Survey of Ohio, 1838, report of Dr. S. P. Hildreth, pages 42 and 43. Fossils which accompany "The Pomeroy Coal Bed" [Redstone].

Location: At Pomeroy, Meigs County.

"In the shale beds, which generally form the roof of this coal, we find innumerable casts and impressions of the foliage and stems of various coal plants, of which have been collected more than twenty species. Amongst them may be recognized of the *Equisetaceae*, the *Calamites* and *Equiseteum* of *Filices*, the *Sphenopteris*, *Glossopteris*, *Neuropteris*, *Pecopteris*, etc. The Lycopodiaceae, such as *Lepidodendron*, *Sigillaria*, etc., are rare in this deposit, but are common in the earlier formed beds. The most interesting feature of the rocks connected with this coal, is the great abundance of fossilized stems and branches of trees, that are found to accompany the coarse sandrocks which lie over the coal, in several localities which have been visited. So few quarries, or excavations, have been yet opened in this rock, that we can only discover them in beds of streams, or situations where the rock has crumbled away by natural causes."

Reference: Section 253, Geological Survey Ohio, Volume 1, page 253.

Location: A section at Pomeroy shows the following strata. Pomeroy topographic sheet.

	Ft.	In.
Shale	6	0
Sandstone, laminated	6	0
Clay shale	10	0
Sandstone	16	0
Not exposed in detail	31	0
Shale, red	6	0
Sandstone, compact	9	0
Shale	18	0
Sandstone, heavy, (*Pomeroy*)	64	0
Shale, sandy, with coal plants	9	0

			Ft.	In.
Coal, top	Pomeroy or Redstone		1	0
Shale	Pomeroy or Redstone		0	2
Coal	Pomeroy or Redstone		4	0
Shale, bituminous, with streaks of coal			1	2
Clay			1	0
Sandstone			8	0
Shale			6	0
Sandstone			2	0
Shale			14	0
Pittsburgh coal not far below.				

Reference: Section 254, Geological Survey Ohio, Volume 1, page 254.

Location: At Coalport (midway between Pomeroy and Middleport) we find the coal (Pomeroy) and its associated strata as follows. Pomeroy topographic sheet.

		Ft.	In.
Sandstone, heavy, not measured.		..	..
Shale, ferruginous, containing coal plants		15	0
Shale, bituminous		0	8
Coal	*Pomeroy or Redstone*	1	6
Coal	*Pomeroy or Redstone*	3	7
Underclay and shale		6	0

Reference: Section 250, Geological Survey Ohio, Volume 1, page 250.

Location: At the Wells bank, a mile east of Pagetown, in the southeastern part of Section 17, Scipio Township, Meigs County, the following measurements were made. Pomeroy topographic sheet.

	Ft.	In.
Sandrock, seen	20	0
Shale, with coal plants	4	0
Coal, [*Pomeroy or Redstone*]	3	6

Reference: First Annual Report on the Geological Survey of Ohio, 1838, Report of Dr. S. P. Hildreth, page 43.

Locations: Branches of Federal Creek, (Morgan and Athens Counties), Leading Creek (western Meigs County), Campaign Creek (northern Gallia County), head of Shale River, Lodi Township, Athens County.

"Fragments of fossilized trees are seen in several of the branches of Federal Creek; the beds of Campaign and Leading Creek, but more abundantly in the heads of Shade River, Township of Lodi, Athens County. The extreme northerly branch of this river, rises in that high ridge of land south of Athens, before noticed, and not more than a mile from the Hockhocking River. About three miles south, this branch becomes a rivulet of ten or twelve feet in width. In the bed of this rivulet, and also in one which heads with it, and puts into the Hockhocking, are found numerous tabular, oval masses of siliceous composition. They are from 4 to 10 inches in thickness, and from 2 to 3 feet in diameter, with others that are smaller. One of the sides is almost invariably concave, or depressed in the center, and the opposite one plane or slightly convex. They are evidently petrifications of some vegetable substance, as the traces of the fibrous structure is very apparent in all the specimens. The form of these masses very much resembles that of the base of the *Stigmaria ficoides*, with the branches all broken off. They are composed of the hardest silicious matter, of a reddish, gray color. . . . Isolated masses are scattered along the bed of the branch for more than a mile, the bottom of which is composed of a slaty sand-rock, deposited in thin layers, highly inclined, and of slight coherence. No specimens were found in place, but they were doubtless originally imbedded in a coarse sand-rock, which lies over the coal. This opinion is strengthened by the fact that portions of the trunks and roots of the fossil trees found lower down the branch, are often ploughed up in the fields, on the hill sides, 50 to 80 feet above the bed. A few miles lower down, and six and a half miles from Athens, the beds of several small streams, all tributaries of Shade, and rising over a space of 8 or 10 square miles of surface, are found strewed with

the segments of trunks of fossil trees, varying in diameter from a few inches to 18 or 20 inches. The larger sections are generally perforated by a circular opening near the center, from 1 to 4 or 5 inches in diameter. The regular shape of the pieces, resembling transverse sections of a log of wood, seems to be the result of a peculiar mineral organization, disposing the fragments to assume a cubic form, had the exterior of the fossil been square instead of circular. The ligneous structure of the original tree was coarse, very distinct, and highly vascular; it is now replaced by silex, in many specimens beautifully agatized. Some of the pieces are filled with perforations, the size of a quill, and larger, which seem to have been made by a worm. This most probably was done by an ancient Teredo, after the trees were torn up, and floated down some river to the ocean. Fragments, three to four feet in length, are the longest yet discovered. The quantity of specimens is so great that we might be led to suppose a whole forest had originally been entombed in this place, covered with beds of a highly silicious quality, and consolidated into sand-rock. These rocks being less dense and compact than the fossilized wood, have, in the course of ages, crumbled into soil, and left the imbedded trees to fall out in fragments, and gradually wash down the slopes of the hills into the beds of the streams, where they are now found. As the age of this rock is long anterior to the Tertiary, these fossil remains are not likely to be allied to any living species of tree which now vegetates in the forests of Ohio. It most probably belongs to the tribe of Gymosperma, of Lindley; a race of plants whose seeds are naked or formed without a pericarpium, or envelope. From the great vascularity of the trunk, and the fact of the fragments almost entirely composed of the shafts of the trees, with few or no branches, we are led to conclude, they may be attached to the order Cycadea, the woody fibre of which is very similar in structure to the coniferae, or pine race, and which are only found in some of the more recent coal deposits."

Reference: Section 286, Geological Survey Ohio, Volume I, pages 287–288.

Location: The following is a section obtained on the land of Philip Haning in Section 32, Lodi Township, Athens County. Pomeroy topographic sheet.

	Ft.	In.
Sandstone, seen, *Pomeroy*	25	0
Sandstone, unevenly bedded, showing part of a trunk of a silicified tree in place	5	0
Shale, blue, with coal plants	5	0
Coal, reported, *Pomeroy* or *Redstone*	1	6
Shale, with nodules of limestone	25	0
Coal, *Pittsburgh.*	8	0
Shale and clay.	12	0

"The above section is of great interest as showing the position of one of the trunks of petrified wood. These trunks are very often found on the upper branches of Shade River, lying in the bed of the stream.

"Great quantities, even tons, of specimens of silicified wood from Shade River, have been obtained to enrich cabinets in various parts of the country. No very minute investigation has as yet [1873] been made of the samples so far as I know. Mr. Leo Lesquereux is now engaged in the study of them, and it is believed that his results will be interesting and valuable. There are doubtless many different kinds of wood, and when specimens are properly prepared for microscopic investigation, the structural differences will be still more apparent. Mr. Lesquereux believes that the fragments of trunks are found in the shales between the two coals [Pittsburgh and Pomeroy], as well as in the sandstone above the upper coal [Pomeroy] where I [Andrews] found them. From repeated visits to this region, I am led to believe that the trees, after drifting about and many of them partly rotting away, were buried in the sand, and while thus buried, were slowly changed into silex from silica derived, probably, from the sand of the sandrock. The portion of a trunk seen in place on the Haning farm, had more than half rotted away before it was silicified. It lies in the sandrock in a horizontal position, and the false bedding of the sandrock around it indicates the rolling of waves upon a sandy beach.

"One of the most interesting of the Shade River petrifications is a peculiar disc, often three or four feet in diameter, composed of a mass of flattened rootlets, resembling somewhat those of *Stigmaria.* These rootlets radiate from a common center, and evidently grew in a dense

bunch around the Psaronius tree. The tree, however, is generally gone, either leaving a cavity in the center of the disc, or a depression upon both the upper and under sides. Many years ago, I [Andrews] found one of these discs, showing the remains of a central trunk. The tree had fallen and evidently pressed upon one side of the mass of rootlets, and had in that position partly rotted away before the whole had become silicified."

MEIGS CREEK OR SEWICKLEY COAL HORIZON

The main field of the Meigs Creek coal extends from the Muskingum River in Morgan County to Short Creek in southern Jefferson County. Locally the overlying shales bear some plant fossils and in a few places they contain much fine material.

Reference: Section 11, Thesis, 1936, John C. Frye, State University of Iowa.
Location: Section measured on west side of Big Run, one and one-fourth miles south of the mouth of Straight Run in western Adams Township, Washington County. Caldwell topographic sheet.

		Feet
Shales, mostly covered		27.5
Sandstone and covered		22.0
Sandstone, ferruginous, dark brown		0.9
Sandstone, gray, with shale partings		5.6
Shale, red, partly covered		7.7
Sandstone		5.0
Shale, mostly covered		15.2
Covered		20.0
Sandstone, fine grained, gray		7.5
Covered		3.0
Shale, red		8.0
Shale, gray		2.3
Sandstone, fine grained, gray		1.7
Shale, fissile, red and gray		7.7
Covered		66.0
Limestones		2.3
Shale, micaceous, dark green		7.5
Sandstone, tan, *Upper Sewickley*		21.5
Shale, dark gray, upper part fissile, contains *Calliptoridium?*, *Neuropteris*, *Nematophyllum*, *Odontopteris*, *Pecopteris*, *Shenophyllum*		3.0
Coal	*Meigs*	0.9
Shale, dark gray	*Creek*	1.1
Coal		1.6
Covered		1.3
Shale, gray and tan		5.0

Reference: Section 661, field notes, Noble County, Stout.
Location: Record located on the East Fork of Duck Creek, one and one-half miles northeast of Lower Salem, south of the stream, near the southwest corner of Section 36 (in part), Salem Township, Noble County, at the coal mine of A. H. Ullman. The record taken is given below. Macksburg topographic sheet.

		Ft.	In.
Sandstone, massive, *Upper Sewickley*		20	0
Shale, calcareous, with many plant fossils		1	1
Shale, coaly		0	1
Coal, good	*Meigs Creek*	2	0
Shale, gray	*Meigs Creek*	0	0½
Coal, fair	*Meigs Creek*	0	1
Clay shale	*Meigs Creek*	1	1
Coal, good	*Meigs Creek*	3	0½
Covered		73	0

Road level, elevation 730 feet.

Permian System

In Ohio the Permian system of rocks extends in a narrow belt along the Ohio River from Jefferson County on the north to Meigs County on the south. The total area is close to 1,830 square miles and the maximum thickness about 625 feet. The system is divided into two major divisions, Washington and Greene series, and these are further subdivided into many members. The rocks of the Permian system, in Ohio, consist largely of shales, sandstones and freshwater limestones. While coal beds are present and about normally spaced they are usually impure and in some cases mere soot streaks of organic matter. As so far examined the fossil plants are confined to the lower or Washington series.

THE WASHINGTON FORMATION[3]

"As indicated elsewhere, the Washington formation begins with the Cassville shale and ends with the Upper Washington limestone or the horizon of the Jollytown "A" coal. This formation, in general, is not very prolific in fossils. It has, however, a better preservation of the Dunkard life than is to be found in the overlying beds. Plants are the most abundant fossils in the Dunkard series. At certain horizons the shales are crowded with plant remains in various stages of preservation. In West Virginia and Pennsylvania, William M. Fontaine and I. C. White found 107 different species of fossil plants in the Cassville shale. Fragments of many of these are to be found in the shales of the same horizon in Ohio.

"The shales of the Washington formation often contain fossil plants. These are usually more abundant in the beds associated with the coal. Most, probably all, of these plants have been found in correlative beds of Pennsylvania and West Virginia.

"The following list represents the more important ones found in Ohio.

Pecopteris imbricata, Fontaine and White
Cassville shale, Paines Run, near Cameron . . (1)
Pecopteris dentata (Bat)
Cassville shale, Paines Run, near Cameron (2)
Pecopteris heeriana, Fontaine and White
Cassville shale, Paines Run, near Cameron . . (3)
Pecopteris subfalcata, Fontaine and White
Cassville shale, Clarington [appears to be Uniontown] . . . . (4)
Pecopteris tenuinervis, Fontaine and White
Cassville shale, Becket Station, also in shales above the Waynesburg 'A' coal . (5)
Neuropteris flexuosa longifolia, Fontaine and White
Cassville shale, Clarington [appears to be Uniontown] . . (6)
Neuropteris sp.
Washington coal, Crabapple.... . . . . (7)
Callipteridium grandifolium, Fontaine and White
Cassville shale, Clarington [appears to be Uniontown] . . . (8)
Callipteridium sp.
Cassville shale, Paines Run, near Cameron....... . . . . (9)
Callipteris sp.
Cassville shale, Vallonia....... .. . .(10)
Callipteridium dawsonianum, Fontaine and White
Cassville shale, Paines Run, near Cameron. . . . .(11)
Rhacophyllum filiciforme majus, Fontaine and White
Cassville shale, Paines Run, near Cameron. . . . .(12)
Alithopteris virginiana, Fontaine and White
Cassville shale, Paines Run, near Cameron.......... ... ...(13)
Sphenophyllum latifolium? Fontaine and White
Upper shales of Washington formation, Tunnel Station .. . .(14)

[3]Geological Survey Ohio, Fourth Series, Bulletin 22, pages 141, 142–143.

Baiera virginiana, Fontaine and White
Washington coal, Crabapple. . ...(15)
Sigillaria sp.
Washington coal, Crabapple..................................(16)
Spore cases
Washington coal, Crabapple..................................(17)
Rhacophyllum filiciforme
Shales above Waynesburg 'A' coal, Clarington..................................(18)
Annularia sp.
Shales above Waynesburg 'A' coal, Clarington..................................(19)
Cordaites sp.
Shales above Waynesburg 'A' coal, Clarington..................................(20)
Calamocladus sp.
Shales above Waynesburg 'A' coal, Clarington..................................(21)"

PAINES RUN LOCALITIES

Paines Run is located north of Cameron in southwestern Switzerland, northeast Adams and west central Salem Townships, Monroe County. The horizon of the Cassville shale is about 840 feet at the mouth of the stream and 885 feet in the northern part of Section 15, Switzerland Township, where it passes below drainage. Three sections are given below:

Reference: Section 424, field notes, Monroe County, Stout.

Location: In hollow west of the stream in the northeast part of Section 14, Adams Township, Monroe County, the following strata were exposed. Clarington topographic sheet.

		Ft.	In.
Shale, gray.		2	3
Limestone, blue, hard.	*Elm Grove*	0	8
Limestone, blue, hard..	*Elm Grove*	0	7
Limestone, blue, nodular..	*Elm Grove*	0	3
Shale, blue	*Elm Grove*	0	1
Limestone, blue, hard..	*Elm Grove*	1	2
Shale, gray, with fossils, *Cassville*.		7	0
Covered.		37	7
Shale, gray, siliceous...		13	0
Shale, bony, dark...	*Uniontown*, not full thickness, elevation 790 feet	0	2
Coal, good..	*Uniontown*, not full thickness, elevation 790 feet	1	8

Reference: Section 422, field notes, Monroe County, Stout.

Location: On Paines Run east of the stream, north of the center of Section 15, Switzerland Township, Monroe County. Clarington topographic sheet. The record taken is given below:

		Ft.	In.
Shale, gray to dark...		10	0
Limestone, hard, blue, blocky...	*Elm Grove*	0	7
Limestone, hard, blue, blocky...	*Elm Grove*	1	9
Shale, dark..	*Elm Grove*	0	5
Limestone, three layers...	*Elm Grove*	0	11
Shale, dark, soft, plant remains, *Cassville*.....		3	5
Shale, dark, carbonaceous.....		0	3
Shale, carbonaceous, hard, bony....		0	1
Coal, rough, *Waynesburg*, elevation 880 feet...		0	10
Shale, bony.......		0	0¼
Clay shale, blue to gray..		5	9
Shale, blue, with ore nodules and thin sandstone layers.......		4	3

Reference: Section 421, field notes, Monroe County, Stout.

Location: In bed of stream near line of Section 15 and Section 16, Switzerland Township, Monroe County. Clarington topographic sheet. The record follows:

		Ft.	In.
Limestone, blue, blocky.	*Elm Grove*	2	2
Limestone, blue, blocky.	*Elm Grove*	0	7
Shale, blue		1	7
Clay shale, dark.	*Cassville*	0	6
Clay shale, bluish gray.	*Cassville*	1	0
Shale, coaly.	*Waynesburg*	0	2½
Coal, bony.	*Waynesburg*	0	1
Coal, good	*Waynesburg*	0	4¾
Clay, impure		1	0

CLARINGTON LOCALITIES

In this locality the Cassville shale is found at an elevation close to 700 feet and the Waynesburg "A" coal at 750 feet.

Reference: Section 154, field notes, Monroe County, Stout.

Location: Up the ravine at the west end of the bridge at Clarington, northwest corner Section 24 and the northeast corner of Section 30, Salem Township, Monroe County, the following beds were measured. Clarington topographic sheet.

		Ft.	In.
Washington series, Permian system:			
Coal prospect, *Washington.*		3	0
Shales, gray, parts covered.		28	0
Coal smut, *Little Washington.*		0	1
Clay shale, dark.		2	11
Sandstone, shaly.		8	0
Shales, gray, mainly siliceous.		29	4
Coal prospect and covered, *Waynesburg* "A".		5	4
Limestone, hard, dark		1	2
Covered.		5	2
Shale and shaly sandstone.		15	0
Sandstone, shaly.		7	0
Covered, Cassville shales here		10	8
Monongahela series, Pennsylvanian system:			
Coal, bony, and shale, dark, *Waynesburg.*		0	6
Shale, gray, and sandstone, shaly.		18	4
Soot streak.		0	1
Clay shale, dark.		3	0
Shale, gray, parts very sandy.		7	5
Shale, dark, argillaceous.		1	0
Coal, shaly, *Little Waynesburg.*		0	3
Clay shale, calcareous, dark.		7	9
Shale and shaly sandstone, gray.		18	0
Shale, gray, siliceous, with plant fossils.		7	0
Coal, good	*Uniontown*	1	9½
Coal, shaly.	*Uniontown*	0	2
Shale, coaly.	*Uniontown*	0	2
Shale, gray.	*Uniontown*	0	2
Coal, fair.	*Uniontown*	0	3½
Shale, gray, calcareous.	*Uniontown*	1	2
Limestone, irregular.	*Uniontown*	1	6
Shale, gray, very siliceous.		5	10
Sandstone, shaly, *Arnoldsburg.*		1	4
Shales, gray to pink.		5	8
Shale, dark.		0	4
Limestone, shaly.	*Arnoldsburg*	1	5
Limestone, hard, light.	*Arnoldsburg*	1	3
End of bridge, elevation 620 feet approximately.		..	..

Reference: Section 152, field notes, Monroe County, Stout.

Location: Section taken along the road that leads from Stillhouse Run, near its mouth, to the ridge north, in the northeastern part of Section 20, Salem Township, Monroe County. Clarington topographic sheet.

		Ft.	In.
Coal blossom, *Washington*		3	0
Shales and covered		11	6
Sandstone, massive	*Mannington*	18	0
Shale, gray	*Mannington*	4	0
Sandstone, massive	*Mannington*	19	0
Shales, gray		13	0
Clay shale, dark		1	0
Coal, weathered, shaly, *Waynesburg "A"*		4	0
Shales, parts covered		29	0
Sandstone, shaly		10	0
Shale, gray, Cassville		8	0
Shale, dark, *Waynesburg* coal horizon		1	0
Shales and shaly sandstone		11	4
Shale, dark		0	8
Shale, gray		6	0
Sandstone, shaly		2	0
Shale, part calcareous		6	0
Covered		22	6
Sandstone, shaly		2	6
Shale, gray		6	10
Sandstone, shaly		1	2
Shale, gray, plant fossils		3	10
Coal, weathered, *Uniontown*		3	2
Shale, gray		12	5
Sandstone, massive		1	5
Shale, gray, siliceous		3	4
Limestone and calcareous shale		1	6
Limestone, hard, light		0	10
Shale, calcareous, with limestone nodules		1	6
Limestone, hard, light		1	6
Valley floor, elevation 650 feet		..	..

VALLONIA LOCALITY

Along Weegee Creek in the vicinity of Vallonia the Cassville shales are found at an elevation close to 950 feet. The Cassville shale is overlain by the Elm Grove limestone and underlain by the Waynesburg coal.

Reference: Section 31, field notes. Belmont County, Stout.

Location: Record taken at Vallonia, along Weegee Creek, south of the center of Section 14, Mead Township, Belmont County. St. Clairsville topographic sheet.

	Ft.	In.
Shale, dark, carbonaceous	2	0
Limestone, *Elm Grove*	1	10
Shale, gray, siliceous, *Cassville*	4	6
Coal blossom, *Waynesburg*	1	0
Shales, gray, part sandy	11	6
Coal, shaly, *Little Waynesburg*, elevation 938 feet	0	3½
Shale, light	0	8
Limestones, massive	3	4
Limestones, calcareous shales and covered	11	4
Sandstone, hard, blue, calcareous	2	0

BECKET STATION LOCALITY

In this locality the Cassville shales are present at an elevation of 1,060 feet. In this area both the associated Elm Grove limestone and the Waynesburg coal are present in good development and act as benches of reference.

Reference: Section 117, field notes, Belmont County, Stout.
Location: Section taken at the trestle of the Ohio River and Western Railroad (abandoned) along Rocky Fork, in the northeastern part of Section 12, Washington Township, Belmont County. Clarington topographic sheet.

		Ft.	In.
Limestone, hard, dark	*Elm Grove*	1	4
Shale, gray	*Elm Grove*	8	1
Limestone, dark, very siliceous	*Elm Grove*	1	8
Shale, siliceous, dark, with plant fossils, Cassville.		4	7
Sandstone, shaly		1	0
Shale, siliceous		0	6
Sandstone, micaceous		0	10
Shale, coaly		0	2
Coal, good, *Waynesburg*		2	3
Shale, gray		0	10
Sandstone, shaly		4	0

CRABAPPLE LOCALITY

North of Crabapple the Waynesburg coal is mined in a small way. It is present at an elevation of 910 feet and the Washington coal lies approximately 100 feet higher.

Reference: Section 70, Geological Survey Ohio, Fourth Series, Bulletin 22, page 70.
Location: Section located north of Crabapple in the north-central part of Section 26, Washington Township, Belmont County. Clarington topographic sheet.

	Ft.	In.
Sandstone, laminated, micaceous, gray, *Lower Marietta.*	16	0
Shales, red and gray, argillaceous, with plant fossils	19	3
Coal and shale, *Washington.*	3	5
Covered	26	8
Shale, argillaceous, blue, with sandy nodules.	10	8
Covered	14	0
Limestone, dark	0	6
Shale, black, carbonaceous, and some coal. At some places this coaly portion thickens to a foot and has been mined, *Waynesburg "A"*	1	10
Limestone, blue-gray, hard	0	10
Limestone, dark-gray, impure	1	1
Shale, dark-gray	1	6
Limestone, gray to yellow.	3	3
Sandstone, massive, gray.	4	7
Shale, gray	7	6
Limestone, gray, with an irregular base	1	6
Shale, soft, gray, with calcareous nodules and black carbonaceous streaks at base	4	5
Shale, gray, contorted, nodular, sandy, micaceous	5	4
Sandstone, gray, shaly, micaceous	2	6
Shale, gray, arenaceous, containing plant remains	4	5
Shale, gray, arenaceous	0	5
Sandstone, gray, arenaceous	0	6
Shale, blue, argillaceous, rather soft	2	0
Coal and carbonaceous shale, a small country mine, *Waynesburg*	3	8

TUNNEL STATION LOCALITY

Reference: Section 130, Geological Survey Ohio, Fourth Series, Bulletin 22, pages 130–131.

Location: "At Tunnel Station, on the Marietta, Columbus and Cleveland Railway, (abandoned) some very good outcrops of small portions of the Dunkard, (upper Washington Series) are to be seen. The grindstone quarries at this place are probably in the Jollytown sandstone, although it may possibly be Hundred in age. Combined section of quarry and tunnel cut on the Marietta, Columbus and Cleveland Railway, near the head of Browns Run, southwest Section 16, Warren Township, Washington County. Parkersburg topographic sheet.

	Ft.	In.
Shales, red and gray, argillaceous, to the top of the Cleveland Stone Company's Quarry on Charles Treachel's land	4	0
Shale, gray, arenaceous	10	8
Sandstone, gray, micaceous, rather massive. This is the rock used for grindstones. Jollytown? sandstone	16	6
Covered interval to bottom of quarry	24	4
Sandstone, gray, micaceous, laminated	1	0
Shale, red and gray, arenaceous	5	0
Covered interval with some weathered red shale exposed	17	4
Shale, red, argillaceous, to top of tunnel cut	6	0
Sandstone, calcareous, shaly, greenish-gray	2	0
Shales, red to greenish-gray	6	4
Sandstone, micaceous, shaly, greenish-gray	3	0
Shale, arenaceous, gray, nodular	0	6
Shale, red, with streaks of gray	0	8
Shale, greenish-gray with streaks of red	1	2
Sandstone, micaceous, nodular	0	3
Shales, red and gray, with nodules	0	9
Shale, red, argillaceous, containing iron nodules	11	3
Sandstone, coarse, bluish to greenish-gray, laminated, this extends to the level of the track at the upper end of the tunnel	7	2

WAYNESBURG COAL HORIZON

Locally the Waynesburg coal is much broken by shale partings, that is, it consists of thin beds of coal in carbonaceous shales which may contain plant fossils.

Reference: Section 28, Thesis, 1936, John C. Frye, State University of Iowa.

Location: A section was measured up the creek bed and road cut from the road intersection, elevation 667 feet, 1.5 miles north of Watertown, Watertown Township, Washington County. Parkersburg topographic sheet.

		Feet
Cover to top of hill		4.0
Sandstone, medium grained, buff, *Lower Marietta*		33.0
Shale, gray and tan		2.7
Clay		0.5
Coal	*Washington*	0.15
Clay	*Washington*	0.5
Coal, shaly	*Washington*	0.4
Shale, maroon, partly covered		2.8
Clay shale, red, partly covered		16.5
Sandstone, lenticular, and shale, tan		8.4
Shale, fissile, tan and red		11.9
Shale, fissile, maroon		4.0
Shale, red and gray		5.3

			Feet
Shale, arenaceous, tan			9.0
Shale, ferruginous, black			0.15
Shale, maroon			7.2
Covered			2.2
Sandstone, medium grained, gray			0.4
Shale, hard, mottled, partly covered			4 8
Shale, gray, passing upward into sandstone			5.2
Shale, highly carbonaceous			1 0
Shale, tan			3.0
Underclay, blue-gray, and shale, tan			0.6
Sandstone, fine-grained, cross-bedded			3 0
Shale, fissile, tan			5 2
Coal	}	*Waynesburg*	0.25
Shale, tan, with abundant plant fossils	}	*Waynesburg*	2.2
Coal, shaly	}	*Waynesburg*	0 15
Shale, gray and tan			13.2
Limestone, hard, gray			5 4
Road intersection, elevation 667 feet			

WAYNESBURG "A" COAL HORIZON

The Waynesburg "A" coal horizon bears some plant fossils in many areas. Probably through careful search some rich deposits may be discovered.

Reference: Section 27, Thesis, 1936, John C. Frye, State University of Iowa.
Location: A section measured along road and draw, 1.5 miles east of Watertown, Central Section 2, Watertown Township, Washington County. Parkersburg topographic sheet.

			Feet
Cover to top of hill			30.0
Shale, arenaceous, tan			10.4
Limestone, argillaceous, buff			0.2
Shale, arenaceous, tan			5.2
Shale and sandstone			3.0
Covered			24.0
Sandstone, fine-grained, buff			4.2
Shale, fissile, maroon			0.5
Shales, red, gray and tan			17.3
Sandstone, fine-grained, light gray			2.0
Shale, arenaceous, red and gray			3 4
Shale, tan, parts covered			38 4
Sandstone, highly micaceous, fine-grained, buff			5 5
Shale, maroon, partly covered			11.6
Shale, arenaceous, tan			2.0
Shale, mostly maroon			12 4
Coal, shaly	}	*Waynesburg "A"*	0 5
Clay, tan	}	*Waynesburg "A"*	0.3
Coal, shaly, carbonaceous	}	*Waynesburg "A"*	0.7
Nematophyllum, Neuropteris and Pecopteris were collected from lower zone.			
Clay shale, tan and gray			5.0
Covered to level of creek above Painter Run			6.0

HIGHER HORIZONS

Reference: Grotto of plants. Observations on the Bituminous Coal deposits of the valley of the Ohio, and the accompanying rock strata; with notices of the fossil Organic remains and the relics of Vegetable and Animal bodies, illustrated by a Geological map, by numerous drawings of plants and shells, and by views of interesting scenery; by Dr. S. P. Hildreth, of Marietta, Ohio. The American Journal of Science, Volume XXIX, January, 1836, pages 18–20.

Location: The grotto is seated on the side of a deep ravine, which the water in running from the hills, has gradually worn in the rocks, at an elevation of one hundred feet above the bed of the river (Ohio). Located two miles below the mouth of the Muskingum River and 660 feet northwest from the bank of the Ohio River, northeast corner of Section 3, Warren Township, Washington County. Marietta topographic sheet.

"At the southern outlet of the Muskingum Valley, two miles below the mouth of the river, and forty rods from the bank of the Ohio, an interesting grotto, has been formed in the sandstone from the gradual disintegration of the rock by a chemical process. The rock itself or rather this stratum (Hundred sandstone) is about 50 feet in thickness. It rests on a bed of argillaceous or slaty marl, (impure fresh-water limestone) two feet thick. The upper portion is ash colored and very heavy, (limestone) and the lower portion of the bed, fourteen inches in thickness, is of a deep rich brown, or red. Its structure is slaty, and it splits easily in the line of stratification into thin layers. It is completely filled with vegetable impressions of the most perfect and beautiful structure; many of them appear to be aquatic plants, but the most abundant are of the genus Neuroptera. If the slaty matrix were less fragile, very perfect specimens could be procured. As it is, they are, in the hands of any one versed in the botany of fossil plants, sufficient to determine the species. Several figures are given of the plants found here, from No. 23 to 26; (pages 10 and 11 of the wood cuts)[4] No. 23 is one of the most beautiful and perfect branches of the arborescent fern that I have ever seen. The foliage is similar to that represented by N. Ad Brongniart in one of his antediluvian trees, as he supposed they appeared when living. I have seen no similar species, described in his work on fossil plants. No. 24 was probably a very porous, thick leaved, aquatic plant, termination ovate, as fragments of the extremities were found, of that shape, cuticle scabrous. The leaf was replaced by a deposit of yellow ochre, one-eighth of an inch in thickness, leaving the outlines and markings of the cuticle on the red shale. A large proportion of the plants at the grotto are replaced by yellow ochre. Several other species are impressed on the same fragment. No. 25 is a very rich fern. Each leaflet appears to have been composed of, or margined by rounded grains, too large and too uniform, for the fruit. The beautiful oblong leaf, No. 26, resembles 'Neuropteris Scheuchzeri,' but is not sufficiently acuminate. Its structure is similar to that of the oleander leaf and is probably a new species. On the same fragment are two species of Neuroptera. Pods and seeds of plants are also common; with the leaf of a thick, aquatic plant, like that of the Nelumbium luteum, passing transversely through the bed, as if they had been inhumed in their growing and natural position. From their undisturbed and perfect condition I am led to conclude that they lived and vegetated on the spot where they are now found. Had they been transported by currents of water, the leaves and branches would have been more confused and broken."

Reference: Section B observations on the Bituminous coal deposits of the valley of the Ohio, and the accompanying rock strata; with notices of the fossil Organic remains and the relics of Vegetable and Animal bodies, illustrated by a Geological map, by numerous drawings of plants and shells, and by views of interesting scenery; by Dr. S. P. Hildreth, of Marietta, Ohio. The American Journal of Science, Volume XXIX, January, 1836, pages 23 and 24.

Location: Section of rock strata at Indian Run, at a point two miles northwest of Marietta, in south-central Muskingum Township, Washington County. Marietta topographic sheet.

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[4]See Journal for Illustrations.

	Ft.	In.
1. Soil and residual	2	0
2. Sandstone, light colored	10	0
3. Sandstone, light colored, coarse grained, (Hundred)	50	0
4. Shale, bituminous, with thin veins of coal of a few inches near the bottom	20	0
5. Limestone, gray	2	0
6. Sandstone, argillaceous, (Upper Marietta)	50	0
7. Marl, brown, with nodules of red oxide of iron, with plant impressions	6	0
8. Sandstone, slaty, (Lower Marietta)	9	0
9. Marl, brown, slaty, with plant impressions	10	0
10. Top of salt well.		

No. 7 is a brown marl, with nodules of red oxide of iron; many of the nodules and flattened pieces contain, when broken, fine impressions of arborescent ferns. Portions of the trunk, two or three feet in length, and three or four inches in diameter, much flattened, are also found on this branch, and probably from this bed. I have fragments, completely replaced by iron ore, in which the woody fibre is very distinct in its large longitudinal fracture. Figures are given at Nos. 27 and 28 (page 12 of the wood cuts) in iron ore from this place. They are both of the genus Neuropteris, but are probably undescribed species. No. 27 resembles Anomopteris, rather more than Neuropteris.

No. 9 is brown slaty marl, upper part of the bed ash colored, lower part, nearly that of Spanish brown, compact and heavy, filled with casts of a thick leaved plant, generally vertical as if buried in a living state. They are too much broken to give definite outlines of their forms, sufficiently correct for a drawing. The middle portion of the bed abounds with impressions of several species of *Neuroptera*. A figure of one of these species is given on No. 29 (page 12 of the wood cuts). The plant is replaced with yellow ochre, and belongs to the arborescent ferns. The upper or ash colored portion of the bed, for about two or three inches in thickness, is filled with the impressions of an asteroid blossom, arranged in rows, upon a stem, sometimes six or eight in a line, the lower half of one resting on the upper half of another. They are of different sizes, but all equal on the same stem, and generally, each floret contains twenty-four petals or rays. The broad leaf of some arundinaceous plant is sometimes seen impressed amongst them. Figure No. 30 (page 9 of the wood cuts) gives a very correct view of their forms and size.

Conclusions

From the evidence obtained in general field work it is thus apparent that plants were abundant through both the Pennsylvanian and Permian cycles of time. The section, with definite plant fossils, from the Sharon of the Pottsville series to the Jollytown of the Greene, is approximately 1,360 feet in thickness. Without search plant fossils are noted on some twenty-six horizons well distributed throughout the column. Careful inspection over wide field will most certainly produce results on each of the fifty-three coal horizons in the geological scale of Ohio.

ADDITIONS TO THE REVISED CATALOGUE OF OHIO VASCULAR PLANTS. XIII[1]

CLYDE H. JONES,
The Ohio State University

In spite of the efforts of the many conscientious collectors who through the years have attempted to build for us in the State Herbarium a permanent record of Ohio's vegetation, some counties are poorly represented. Carroll County, located just south of the glacial boundary in the rugged plateau section of the state, was an outstanding example. Last summer the Ohio Conservation Laboratory was held at Camp Muskingum on Leesville Lake in that county. Students and staff members of the school collected representative specimens of the vegetation in that area to be deposited in the herbarium at the Laboratory and in the State Herbarium. The work will continue this summer.

Three particularly interesting contributions came to the State Herbarium this year. The first two were collected hundreds of miles outside their usually accepted ranges: *Berchemia scandens* the Rattan-vine and *Carex caroliniana* the Carolina Sedge. The third, *Asplenium trudelli* Trudell's Spleenwort, is a hybrid between *Asplenium montanum* the Mountain Spleenwort and *Asplenium pinnatifidum* the Pinnatifid Spleenwort.

The numerous other valuable specimens and collections which have been received during the year are being preserved and will be identified and reported as rapidly as time and assistance permit. We are indeed happy that the hobby of collecting has not been a war casualty among Ohio amateurs.

6. *Botrychium dissectum* Spreng. Cutleaf Grape-fern. Camp Muskingum, Carroll Co. Adele Konopka.
8. *Osmunda regalis* L. Royal-fern. Camp Muskingum, Carroll Co. Clyde H. Jones.
10. *Osmunda cinnamomea* L. Cinnamon-fern. Camp Muskingum, Carroll Co. Clyde H. Jones.
11. *Polypodium virginianum* L. Virginia Polypody. Camp Muskingum, Carroll Co. Adele Konopka.
22.1. *Asplenium trudelli* Wherry. Trudell's Spleenwort. (*A. pinnatifidum* x *A. montanum*). Fairfield and Pike Co. Floyd Bartley and Leslie Pontius.
32. *Camptosorus rhizophyllus* (L.) Link. Walking-fern. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
38. *Dryopteris marginalis* (L.) Gr. Marginal Shield-fern. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
39. *Dryopteris intermedia* (Muhl.) Gr. American Shield-fern. Camp Muskingum, Carroll Co. Arthur R. Harper.
45. *Cystopteris fragilis* (L.) Bernh. Fragile Bladder-fern. Camp Muskingum, Carroll Co. Adele Konopka.
46. *Woodsia obtusa* (Spreng.) Torr. Blunt-lobed Woodsia. Camp Muskingum, Carroll Co. Clyde H. Jones.
54. *Equisetum praealtum* Raf. Great Scouring-rush. Camp Muskingum, Carroll Co. Adele Konopka.
61. *Equisetum arvense* L. Field Horsetail. Camp Muskingum, Carroll Co. Adele Konopka.
65. *Lycopodium clavatum* L. Common Club-moss. Camp Indianola, Fairfield Co. Gene Rea.
82.1. *Sagittaria longirostra* (Micheli) J. G. Sm. Long-beaked Arrow-head. Hocking Co. Floyd Bartley and Leslie Pontius.
119. *Philotria canadensis* (Mx.) Britt. Common Water-weed. Camp Muskingum, Carroll Co. Arthur R. Harper.
122.1. *Sparganium americanum* Nutt. Nuttall's Bur-reed. Hocking Co. Floyd Bartley and Leslie Pontius.

[1]Papers from the Department of Botany, The Ohio State University, No. 486.

131. *Arisaema dracontium* (L.) Schott. Green-dragon. Camp Muskingum, Carroll Co. Arthur R. Harper.
140. *Scirpus lineatus* Mx. Reddish Bulrush. Malvern, Carroll Co. Clyde H. Jones.
144. *Scirpus polyphyllus* Vahl. Leafy Bulrush. Camp Muskingum, Carroll Co. Arthur R. Harper. Wayne Co. L. S. Hopkins.
146. *Scirpus validus* Vahl. Great Bulrush. Wayne and Ashland Co. L. S. Hopkins. Camp Muskingum, Carroll Co. Arthur R. Harper.
148. *Scirpus americanus* Pers. Chair-maker's Clubrush. Ashland Co. L. S. Hopkins.
156. *Eleocharis quadrangulata* (Mx.) R. & S. Four-angled Spike-rush. Ashland Co. L. S. Hopkins.
162. *Eleocharis palustris* (L.) R. & S. Creeping Spike-rush. Wayne and Ashland Co. L. S. Hopkins.
165. *Eleocharis obtusa* (Willd.) Schultes. Blunt Spike-rush. Summit and Portage Co. L. S. Hopkins.
168. *Cyperus strigosus* L. Straw-colored Cyperus. Camp Muskingum, Carroll Co. Arthur R. Harper.
292. *Carex caroliniana* Schw. Carolina Sedge. Malvern, Carroll Co. Clyde H. Jones.
297. *Carex shortiana* Dew. Short's Sedge. Good Hope Twp., Hocking Co. Floyd Bartley.
323. *Carex lupulina* Muhl. Hop Sedge. Malvern, Carroll Co. Clyde H. Jones.
333.1. *Bromus latiglumis* (Shear). Hitch. Wayne Co. L. S. Hopkins.
334. *Bromus purgans* L. Hairy Brome-grass. Carroll Co. Ralph Kriebel.
338. *Festuca elatior* L. Tall Fescue-grass. Portage Co. L. S. Hopkins.
348. *Panicularia canadensis* (Mx.) Ktz. Rattlesnake Manna-grass. Portage Co. L. S. Hopkins.
350. *Panicularia nervata* (Willd.) Ktz. Nerved Manna-grass. Camp Muskingum, Carroll Co. Arthur R. Harper.
352. *Panicularia pallida* (Torr.) Ktz. Pale Manna-grass. Portage Co. L. S. Hopkins
357. *Poa debilis* Torr. Weak Spear-grass. Portage Co. L. S. Hopkins.
370. *Eragrostis purshii* Schrad. Pursh's Love-grass. Wayne Co. James F. Machwart.
371. *Eragrostis pilosa* (L.) Beauv. Tufted Love-grass. Wayne Co. L. S. Hopkins.
386. *Trisetum pennsylvanicum* (L.) Beauv. Marsh False-oats. Good Hope Twp., Hocking Co. Floyd Bartley.
393. *Nothoholcus lanatus* (L.) Nash. Velvet-grass. Camp Muskingum, Carroll Co. Arthur R. Harper and Ralph Kriebel.
421. *Muhlenbergia schreberi* Gmel. Spreading Muhlenbergia. Camp Muskingum, Carroll Co. Arthur R. Harper.
424. *Oryzopsis racemosa* (Sm.) Ricker. Black-fruited Mountain-rice. Geauga Co. L. S. Hopkins.
433. *Phalaris arundinacea* L. Reed Canary-grass. Camp Muskingum, Carroll Co. Arthur R. Harper.
439. *Agropyron repens* (L.) Beauv. Couch-grass. Gallia Co. E. Ray Bailey via C. J. Willard.
446. *Elymus canadensis* L. Nodding Wild-rye. Belpre Twp., Washington Co. Otis R. Kiracofe. Wayne and Highland Co. L. S. Hopkins.
464. *Panicum stipitatum* Nash. Long Panic-grass. Trumbull Co. L. S. Hopkins.
469. *Panicum miliaceum* L. Millet Panic-grass. Belmont Co. Emma E. Laughlin.
498. *Panicum boscii* Poir. Bosc's Panic-grass. Camp Muskingum, Carroll Co. Arthur R. Harper.
503. *Echinochloa crus-galli* (L.) Beauv. Common Barnyard-grass. Camp Muskingum, Carroll Co. Arthur R. Harper.
562. *Medeola virginiana* L. Indian Cucumber-root. Camp Muskingum, Carroll Co. Adele Konopka.
571. *Vagnera racemosa* (L.) Mor. Panicled False Solomon's-seal. Camp Muskingum, Carroll Co. Arthur R. Harper.
593. *Juncus effusus* L. Common Rush. Ashland Co. L. S. Hopkins.
600. *Juncus aristulatus* Mx. Small-headed Grass-leaf Rush. Wayne Co. L. S. Hopkins.
660. *Peramium pubescens* (Willd.) MacM. Downy Rattlesnake-plantain. Camp Muskingum, Carroll Co. Adele Konopka.
680. *Asimina triloba* (L.) Dunal. Papaw. Carroll Co. Harold S. Vasbinder.
714. *Hepatica triloba* Chaix. Round-lobed Liver-leaf. Camp Muskingum, Carroll Co. Adele Konopka.
728. *Thalictrum polygamum* Muhl. Tall Meadow-rue. Camp Muskingum, Carroll Co. Adele Konopka.
740. *Benzoin aestivale* (L.) Nees. Spicebush. Camp Muskingum, Carroll Co. Adele Konopka.
777. *Radicula palustris* (L.) Moench. Marsh Yellow-cress. Camp Muskingum, Carroll Co. Arthur R. Harper. Monroe Co. Clyde H. Jones.

857. *Oxalis stricta* L. Upright Wood-sorrel. Camp Muskingum, Carroll Co. Adele Konopka.
882. *Polygala viridescens* L. Purple Milkwort. Camp Muskingum, Carroll Co. Adele Konopka.
885. *Polygala ambigua* Nutt. Loose-spiked Milkwort. Camp Muskingum, Carroll Co. Arthur R. Harper.
931. *Hibiscus trionum* L. Bladder Ketmia. Carroll Co. Harold S. Vasbinder.
932. *Tilia americana* L. American Linden. Camp Muskingum, Carroll Co. Clyde H. Jones.
944. *Hypericum mutilum* L. Small-flowered St. John's-wort. Camp Muskingum, Carroll Co. Arthur R. Harper.
1003. *Alsine longifolia* (Muhl.) Britt. Longleaf Stitchwort. Camp Muskingum, Carroll Co. Adele Konopka.
1015. *Lychnis alba* Mill. White Lychnis. Camp Muskingum, Carroll Co. Adele Konopka.
1018. *Silene stellata* (L.) Ait.f. Starry Campion. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
1035. *Dianthus armeria* L. Deptford Pink. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
1040. *Portulaca oleracea* L. Purslane. Camp Muskingum, Carroll Co. Arthur R. Harper.
1044. *Allionia nyctaginea* Mx. Heart-leaf Umbrella-wort. Scioto Co. Conrad Roth.
1083. *Naumburgia thyrsiflora* (L.) Duby. Tufted Yellow Loose-strife. Portage Co. L. S. Hopkins.
1104. *Tiniaria convolvulus* (L.) Webb. & Moq. Black Bindweed. Camp Muskingum, Carroll Co. Adele Konopka.
1108. *Tracaulon sagittatum* (L.) Small. Arrow-leaf Tear-thumb. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
1116. *Persicaria lapathifolia* (L.) S. F. Gr. Pale Persicaria. Camp Muskingum, Carroll Co. Adele Konopka.
1130. *Geum virginianum* L. Rough Avens. Camp Muskingum, Carroll Co. Arthur R. Harper.
1135. *Potentilla monspeliensis* L. Rough Cinquefoil. Camp Muskingum, Carroll Co. Arthur R. Harper.
1164. *Opulaster opulifolius* (L.) Ktz. Ninebark. Camp Muskingum, Carroll Co. Adele Konopka.
1166. *Spiraea tomentosa* L. Steeple-bush. Carroll Co. Clyde H. Jones.
1170. *Rosa setigera* Mx. Prairie Rose. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
1187. *Prunus nana* DuRoi. Choke Cherry. Camp Muskingum, Carroll Co. Arthur R. Harper.
1237. *Chamaecrista nictitans* (L.) Moench. Small-flowered Sensitive-pea. Tuscarawas Co. Earl Jones via C. J. Willard.
1300. *Vicia cracca* L. Cow Vetch. Camp Muskingum, Carroll Co. Adele Konopka.
1321.1. *Pueraris thunbergiana* (Sieb. & Zucc.) Benth. Kudzu. Introduced. Hamilton Co. Eleanor Knoechel.
1348. *Parsonsia petiolata* (L.) Rusby. Blue Waxweed. Camp Muskingum, Carroll Co. Harold S. Vasbinder.
1351.1. *Berchemia scandens* (Hill) Trelease. Rattan-vine. Cranberry Island, Buckeye Lake, Licking Co. L. E. Hicks via Floyd Bartley.
1355. *Rhamnus lanceolata* Pursh. Lance-leaf Buckthorn. Camp Muskingum, Carroll Co. Clyde H. Jones.
1362. *Vitis bicolor* LeC. Winter Grape. Camp Muskingum, Carroll Co. Arthur R. Harper.
1367. *Euonymus atropurpureus* Jacq. Wahoo. Good Hope Twp., Hocking Co. Richard T. Wareham and John N. Wolfe. Carroll Co. Harold S. Vasbinder.
1385. *Acer rubrum* L. Red Maple. Camp Muskingum, Carroll Co. Adele Konopka.
1395. *Hamamelis virginiana* L. Witch-hazel. Camp Muskingum, Carroll Co. Adele Konopka.
1417. *Fagus grandifolia* Ehrh. American Beech. Camp Muskingum, Carroll Co. Adele Konopka.
1422. *Quercus bicolor* Willd. Swamp White Oak. Camp Muskingum, Carroll Co. Clyde H. Jones.
1425. *Quercus macrocarpa* Mx. Bur Oak. Carroll Co. Harold S. Vasbinder.
1431. *Quercus coccinea* Wang. Scarlet Oak. Camp Muskingum, Carroll Co. Clyde H. Jones.
1432. *Quercus borealis* Michx. var. *maxima* (Marsh.) Ashe. Red Oak. Camp Muskingum, Carroll Co. Adele Konopka.
1435. *Ostrya virginiana* (Mill.) Willd. Hop-hornbeam. Camp Muskingum, Carroll Co. Adele Konopka.
1453. *Juglans cinerea* L. Butternut. Camp Muskingum, Carroll Co. Adele Konopka.
1461. *Populus deltoides* Marsh. Cottonwood. Camp Muskingum, Carroll Co. Clyde H. Jones.
1465. *Salix nigra* Marsh. Black Willow. Belpre Twp., Washington Co. Otis R. Kiracofe.

1472. *Salix interior* Row. Sandbar Willow. Belpre Twp., Washington Co. Otis R. Kiracofe.
1535. *Aristolochia serpentaria* L. Virginia Snakeroot. Camp Muskingum, Carroll Co. Clyde H. Jones.
1551. *Pyrola elliptica* Nutt. Shinleaf Wintergreen. Camp Muskingum, Carroll Co. Adele Konopka.
1568. *Diospyros virginiana* L. Persimmon. Carroll Co. Harold S. Vasbinder.
1580. *Phlox stolonifera* Sims. Creeping Phlox. Fairfield Co. John N. Wolfe.
1606.1. *Heliotropium indicum* L. Indian Heliotrope. Introduced. Scioto Co. Conrad Roth.
1621. *Sabbatia angularis* (L.) Pursh. Square-stemmed Sabbatia. Camp Muskingum, Carroll Co. Arthur R. Harper.
1637. *Apocynum medium* Greene. Intermediate Dogbane. Camp Muskingum, Carroll Co. Arthur R. Harper.
1638. *Apocynum cannabinum* L. Indian Hemp. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
1646. *Asclepias incarnata* L. Swamp Milkweed. Camp Muskingum, Carroll Co. Adele Konopka.
1653. *Asclepias quadrifolia* Jacq. Fourleaf Milkweed. Camp Muskingum, Carroll Co. Clyde H. Jones.
1682. *Verbascum blattaria* L. Moth Mullen. Camp Muskingum, Carroll Co. Adele Konopka.
1698. *Mimulus alatus* Soland. Sharp-winged Monkey-flower. Camp Muskingum, Carroll Co. Clyde H. Jones.
1701. *Gratiola neglecta* Torr. Clammy Hedge-hyssop. Camp Muskingum, Carroll Co. Arthur R. Harper.
1717. *Veronicastrum virginicum* (L.) Farw. Culver's-root. Camp Muskingum, Carroll Co. Arthur R. Harper and Clyde H. Jones.
1721. *Veronica americana* Schwein. American Speedwell. Camp Muskingum, Carroll Co. Arthur R. Harper and Clyde H. Jones.
1738. *Linaria linaria* (L.) Karst. Yellow Toadflax. Camp Muskingum, Carroll Co. Arthur R. Harper.
1767. *Lappula virginiana* (L.) Greene. Virginia Stickseed. Camp Muskingum, Carroll Co. Clyde H. Jones.
1788. *Verbena hastata* L. Blue Vervain: Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
1798. *Teucrium canadense* L. American Germander. Camp Muskingum, Carroll Co. Clyde H. Jones.
1821. *Lycopus americanus* Muhl. Cutleaf Water-hoarhound. Camp Muskingum, Carroll Co. Arthur R. Harper.
1826. *Collinsonia canadensis* L. Stone-root. Camp Muskingum, Carroll Co. Harold S. Vasbinder.
1829. *Koellia pilosa* (Nutt.) Britt. Hairy Mountain-mint. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
1842. *Agastache nepetoides* (L.) Ktz. Catnip Giant-hyssop. Carroll Co. Harold S. Vasbinder.
1846. *Glecoma hederacea* L. Ground-ivy. Camp Muskingum, Carroll Co. Adele Konopka.
1867. *Monarda fistulosa* L. Wild Bergamot. Camp Muskingum, Carroll Co. Clyde H. Jones.
1868. *Monarda mollis* L. Canescent Wild Bergamot. Camp Muskingum, Carroll Co. Arthur R. Harper.
1880. *Plantago aristata* Mx. Large-bracted Plantain. Malvern, Carroll Co. Arthur R. Harper.
1899. *Daucus carota* L. Wild Carrot. Camp Muskingum, Carroll Co. Adele Konopka.
1902. *Deringa canadensis* (L.) Ktz. Honewort. Camp Muskingum, Carroll Co. Clyde H. Jones.
1936. *Cornus amomum* Mill. Silky Dogwood. Camp Muskingum, Carroll Co. Adele Konopka.
1948. *Nyssa sylvatica* Marsh. Sour Gum or Tupelo. Camp Muskingum, Carroll Co. Adele Konopka.
1952. *Mitchella repens* L. Partridge-berry. Camp Muskingum, Carroll Co. Adele Konopka.
1964. *Galium asprellum* Mx. Rough Bedstraw. Camp Muskingum, Carroll Co. Arthur R. Harper.
2009. *Campanula americana* L. Tall Bellflower. Camp Muskingum, Carroll Co. Arthur R. Harper and Clyde H. Jones.
2014. *Specularia perfoliata* (L.) A.DC. Venus'-looking-glass. Camp Muskingum, Carroll Co. Adele Konopka.
2019. *Lobelia inflata* L. Indian Tobacco. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.
2072. *Bidens, laevis* (L.) B. S. P. Smooth Bur-marigold. Camp Muskingum, Carroll Co. Harold S. Vasbinder.
2120. *Solidago bicolor* L. White Goldenrod. Carroll Co. Harold S. Vasbinder.

2132. *Solidago rugosa* Mill. Wrinkled-leaf Goldenrod. Good Hope Twp., Hocking Co. Richard T. Wareham and John N. Wolfe.
2137. *Solidago juncea* Ait. Plume Goldenrod. Camp Muskingum, Carroll Co. Arthur R. Harper and Harold S. Vasbinder.
2141. *Euthamia graminifolia* (L.) Nutt. Bushy Fragrant Goldenrod. Camp Muskingum, Carroll Co. Arthur R. Harper and Harold S. Vasbinder.
2145. *Sericocarpus asteroides* (L.) B. S. P. Toothed White-top Aster. Camp Muskingum, Carroll Co. Arthur R. Harper.
2158. *Aster puniceus* L. Purple-stem Aster. Carroll Co. Harold S. Vasbinder.
2163. *Aster prenanthoides* Muhl. Crooked-stem Aster. Carroll Co. Harold S. Vasbinder.
2170. *Aster multiflorus* Ait. Dense-flowered Aster. Good Hope Twp., Hocking Co. Richard T. Wareham and John N. Wolfe.
2176. *Aster ericoides* L. White Heath Aster. Carroll Co. Harold S. Vasbinder.
2194. *Eupatorium urticaefolium* Reich. White Snake-root. Camp Muskingum, Carroll Co. Arthur R. Harper and Harold S. Vasbinder.
2235. *Synosma suaveolens* (L.) Raf. Sweet-scented Indian-plantain. Athens Co. Walter P. Porter and P. S. Wamsley.
2237. *Mesadenia atriplicifolia* (L.) Raf. Pale Indian-plantain. Camp Muskingum, Carroll Co, Adele Konopka.
2250. *Cirsium odoratum* (Muhl.) Britt. Fragrant Thistle. Camp Muskingum, Carroll Co. Arthur R. Harper.
2252. *Cirsium arvense* (L.) Scop. Canada Thistle. Camp Muskingum, Carroll Co. Arthur R. Harper.
2262. *Chichorium intybus* L. Chicory. Camp Muskingum, Carroll Co. Adele Konopka.
2265. *Krigia virginica* (L.) Willd. Virginia Dwarf-dandelion. Nettle Lake, Williams Co. Floyd Bartley and Leslie Pontius.
2281. *Hieracium aurantiacum* L. Orange Hawkweed. Camp Muskingum, Carroll Co. Adele Konopka.
2282. *Hieracium pratensis* Tausch. Field Hawkweed. Camp Muskingum, Carroll Co. Adele Konopka.
2292. *Nabalus altissimus* (L.) Hook. Tall Rattlesnake-root. Carroll Co. Harold S. Vasbinder.
2295.1. *Iva ciliata* Willd. Rough Marsh Elder. Sells Lake, Athens Co. Walter P. Porter and P. S. Wamsley.
2299. *Sonchus asper* (L.) Hill. Spiny Sow-thistle. Camp Muskingum, Carroll Co. Arthur R. Harper and Adele Konopka.

A SYSTEMATIC STUDY OF THE MAIN ARTERIES IN THE REGION OF HEART—AVES XV.

GAVIIFORMES—PART 1[1]

FRED H. GLENNY[2]

As in other recent studies on the main arteries in the neck and thorax of birds, the writer herein presents the basic arrangement-pattern with such variations as were observed in two species of North American Loons. The present paper is limited to these two forms due to the lack of other species of birds in this Order. This limitation is in part due to the present world conditions. Although the writer had previously planned to discuss a larger number of species in each subsequent paper, it was finally decided that it might be well to present such information as has already been obtained, and such other observations as may be made at a later time would be presented in subsequent papers on this subject. As a result, adequate comparisons between these two species and other species of this order, as well as comparisons between different families of this order, cannot be drawn at the present time.

MATERIALS

Two specimens of each of the two species studied were dissected and diagrams of the arrangement-patterns of the arteries of the neck and thorax prepared. Specimens were made available for this work by the Royal Ontario Museum of Zoology, Toronto, Canada.

Common Loon, *Gavia immer* Linné.

Red-throated Loon, *Gavia stellata* (Pontoppiden).

OBSERVATIONS

As in other birds, the right systemic (4th aortic) arch (3) alone remains as the functional arch of the aorta. The innominate arteries (2) arise from the common aortic root (1), and pass anteriorly to the left and right before dividing to form the common carotid (8) and subclavian (9) arteries.

The subclavian artery gives rise to the coracoid major (10), axillary (13), intercostal (14), and two pectoral (15) arteries in order. The sternotracheal artery (11) arises as a branch of the coracoid major artery. The coracoid minor artery (12) arises from the ventral face of the subclavian artery—opposite the axillary artery—in *Gavia immer*, and from the axillary artery in *Gavia stellata*. The ductus shawi (16) arises from the common carotid artery (8) and sends off branches to the oesophagus, bronchi, and connective tissues in the region of the heart; to the syrinx and trachea (17) and to the oesophagus above the furcula (18). In *Gavia stellata*, an accessory ascending oesophageal artery (23) arises from the left common carotid artery near its point of bifurcation; an accessory meso-oesophageal artery (24) arises from the right common carotid artery; the thyroid arteries arise from these accessory oesophageal arteries (23 and 24). In *Gavia immer*, the thyroid arteries arise variously from the common carotids or one of their branches, chiefly in the region of the ductus shawi.

The common carotid arteries divide to form the superficial cervical arteries (20) and the internal carotid (trunk) arteries (22). Shortly after its origin from the common carotid, the superficial cervical artery gives rise to the scapular artery (19). The right superficial cervical artery serves as the ascending oesophageal artery in the adult bird. The vertebral arteries (21) arise from the internal carotid (trunk) arteries just after the origin of the superficial cervicals.

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[1]Contributions from the Department of Zoology, University of Toronto, Canada.

[2]Formerly Assistant, Department of Zoology, University of Toronto, Toronto, Canada; now in active service with the United States Army.

Posteriorly, the ligamentous vestige of the left radix aortae—the ligamentum aortae (5)—and the right ligamentum botalli (6) persist. The ligamentum aortae (5) maintains its connection between the left pulmonary arch (7) and the distal portion of the right radix aortae (4), while the ligamentum botalli maintains its proximal attachment with the right pulmonary artery and its distal connection with the right radix aortae.

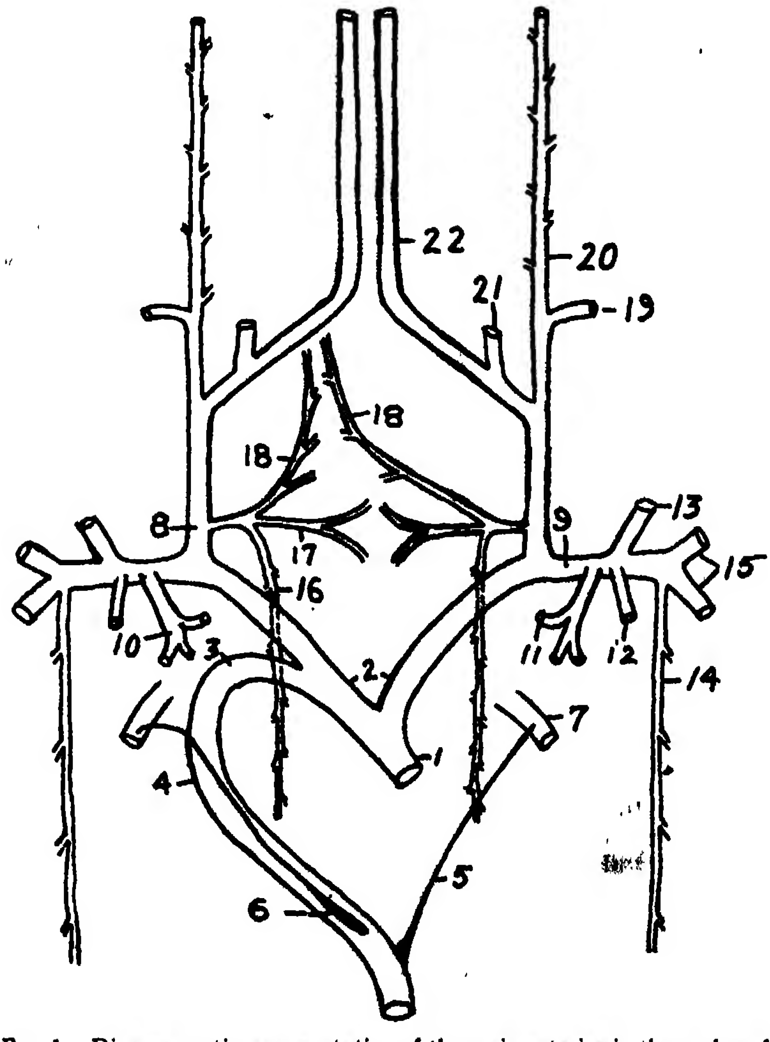

FIG. 1. Diagrammatic representation of the main arteries in the neck and thorax of *Gavia immer*. Ventral view.

KEY TO FIGURES

1. Aortic root; 2. Innominate arteries; 3. Right systemic (4th aortic) arch; 4. Right radix aortae; 5. Left ligamentum aortae; 6. Right ligamentum botalli; 7. pulmonary artery (pulmonary or 6th aortic arch); 8. Common carotid artery; 9. Subclavian artery; 10. Coracoid major artery; 11. Sternotracheal artery; 12. Coracoid minor artery; 13. Axillary artery; 14. Intercostal artery; 15. Pectoral arteries; 16. Ductus shawi; 17. Syringo-tracheal artery; 18. Meso-oesophageal artery; 19. Scapular artery; 20. Superficial cervical arteries (serves as the ascending oesophageal artery on the right side); 21. Vertebral artery; 22. Internal carotid (trunk) arteries; 23. Accessory ascending oesophageal artery; 24. Accessory meso-oesophageal artery; 25. Thyroid arteries.

CONCLUSIONS

In basic arrangement-pattern, the main arteries of the neck and thorax of these two species of Loons are alike. Only minor differences in origin or arrangement of accessory oesophageal arteries are to be noted. Whether or not these minor differences are of any value cannot be evaluated at the present time.

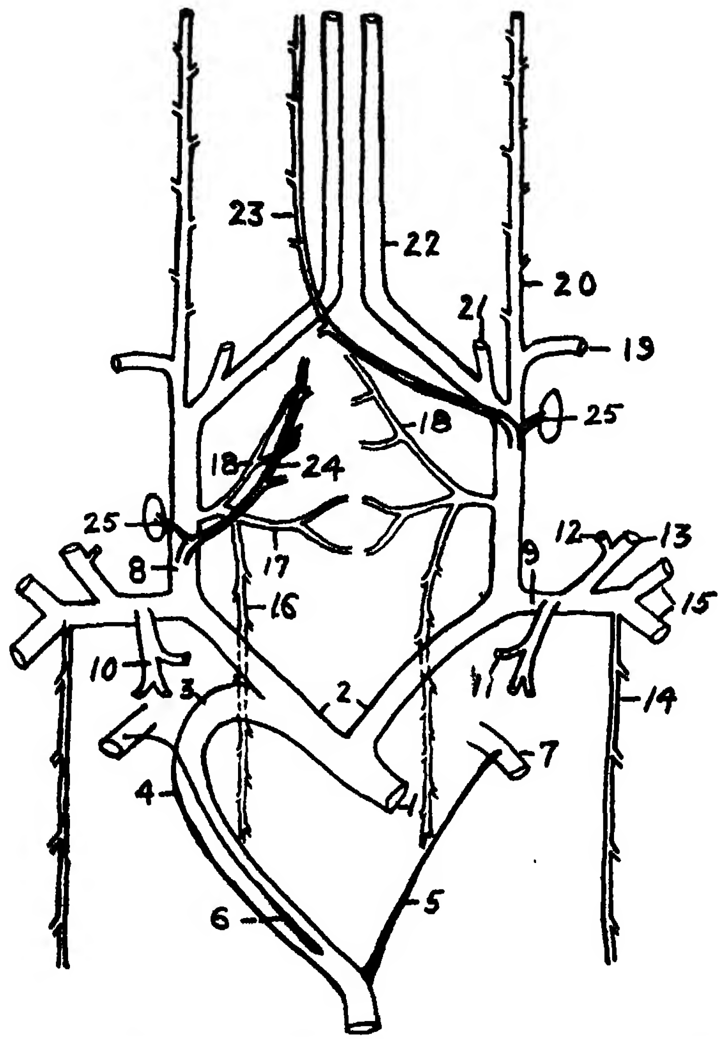

FIG. 2. Diagrammatic representation of the main arteries in the neck and thorax of *Gavia stellata*. Ventral view.

Origin of the coracoid minor artery in the two species may later prove to be of some minor significance. If this group of birds is in a "fluid" state of evolution—or in a state of "flux"—these differences may become increasingly more significant.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation for the assistance given him, in this series of studies, by the staff of the Royal Ontario Museum of Zoology, and to Dr. E. Horne Craigie, Department of Zoology, University of Toronto, for his many helpful suggestions in the course of these studies.

A SERIES OF FIVE MULTIPLE ALLELES[1]

DAVID C. RIFE,[2]
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In 1937 Boye and Rife (1) reported a single pair of alleles as being responsible for a solid purple leaf color versus pattern (brown or red area in central portion of upper epidermis of otherwise green leaves). Purple (P) is dominant to pattern (p). The difference between the solid green of the Golden Bedder variety and pattern was likewise shown to be due to a single pair of alleles, solid green being dominant to pattern. In a later investigation Boye (2) found a series of three multiple alleles to be responsible for these three leaf color variations; solid purple (P), solid green (p^G) and pattern (p), as well as for a new phenotype, gray (Pp^G). Boye (3) also found a new allele (p^S) which in the homozygous state results in solid green leaves. It is incompletely dominant to pattern, in the heterozygous condition resulting in a new phenotype, known as spotted. (Numerous small brown or red spots on the upper epidermis of otherwise green leaves.) The various phenotypes and genotypes involving these alleles are shown in Table I.

This paper is concerned with a fifth allele of the same series. A plant which at first was thought to be of genotype PP or Pp, was later observed to differ in certain respects. The leaf color became such an intense purple as to appear black. The entire calyxes were dark purple, and the petals were dark blue. (Plants of genotypes PP and Pp have light blue petals and green calyxes with red bases.) The purple calyx color was maintained, even after the plant reached maturity and was dried out.

A large number of selfed seeds were produced by this plant. The resulting seedlings all appeared to be purple, and because of cramped facilities most of them were discarded. The remaining plants later proved to be of three types, the differences becoming more apparent as they became larger. Some showed the characteristics of plants of genotypes PP and Pp, some developed the black color of the parent, and the others were of a new phenotype, an uneven purple leaf color. Upon flowering, the petals were of a dark purple color, while the calyxes were green with purple at their bases. These observations suggested the likelihood that the parent plant was heterozygous for two kinds of purple, P and a gene responsible for the new phenotype, uneven purple. We shall use the symbol P^L to designate this allele.

Presumably the plants showing uneven purple leaves were homozygous, of genotype P^LP^L. One of them was crossed with a gray plant ($P\,p^G$) and produced 9 offspring with black leaves, and 6 with non-uniform, gray leaves. The blacks were assumed to be of genotype P^LP, and the non-uniform grays of genotype

[1]Genetic Studies of Coleus. No. V.

[2]Genetics Laboratory, Department of Zoology and Entomology.

$P^L p^G$. Both the black and the uneven gray plants were crossed with pattern. (Tables II and III.) Offspring of black x pattern (P^LP x pp) occurred in approximately equal numbers of typical purple (Pp) and uneven purple (P^Lp). Offspring of uneven gray x pattern Pp^G x pp) likewise occurred in approximately equal numbers of solid green (p^Gp) and light, uneven purple (Pp^L). The fact that only two phentypes were produced from each of these back crosses confirms the hypothesis that a new allele (P^L), rather than another pair of factors, is responsible for these variations.

A black plant (P^LP) was crossed with a green one of genotype p^Gp. As shown in Table IV, four kinds of offspring were produced, in approximately equal numbers. The leaves of plants of genotype P^Lp^G differ from those of genotype Pp^G principally in the distribution of anthocyanin, it being much more uneven in plants of genotype P^Lp^G.

When selfed, plants of genotype Pp^G produced offspring in the approximate ratio of 1 uneven purple; 2 uneven gray; 1 green (see Table V). A plant of genotype P^LP was crossed with one of genotype p^Sp^S, but no differences were noted among the offspring. All had brown leaves, like plants of genotype Pp^S.

All plants possessing the gene P^L produce dark blue flowers, and a dark purple color at the base of the calyx. No other alleles in this series produce this effect, except the combination Pp^S. The gene P produces red at the base of the calyx, while the genes p^S, p^G and p produce solid green calyxes. The genes p^S, p^G and p produce light blue petals. In respect to calyx color, red (P) is dominant to solid green (p^S, p^G and p), while purple (P^L) is dominant to both red and solid green. In respect to petal color, dark blue (P^L) is dominant to light blue. The genotypic combinations P^LP and Pp^S produce copigmentation effects.

TABLE I

Genotypes and phenotypes of the purple allelic series

Genotype	*Leaf color*	*Calyx color*	*Petal color*
P^LP^L	Uneven purple	Purple at base	Dark blue
P^LP	Black	Solid purple	" "
P^Lp^S	Brown	Purple at base	" "
P^Lp^G	Uneven gray	" " "	" "
P^Lp	" purple	" " "	" "
P P	Even purple	Red at base	Light "
P p^S	Brown	Purple at base	Dark "
P p^G	Even gray	Red at base	Light blue
P p	Even purple	" " "	" "
p^Sp^G	Solid green	Solid green	" "
p^Sp^S	" "	" "	" "
p^Gp^G	" "	" "	" "
p^Gp	" "	" "	" "
p^Sp	Spotted	" "	" "
p p	Pattern	" "	" "

TABLE II

$P^LP \times pp$

Offspring

	Observed	Calculated	
P^Lp	69	71	df = 1
			x^2 = 0.112
Pp	73	71	p = 0.7 —0.95

TABLE III

$P^Lp^G \times pp$

Offspring

	Observed	Calculated	
P^Lp	67	69.5	df = 1
			x^2 = 0.179
P^Gp	72	69.5	p = 0.5 – 0.7

TABLE IV

$P^LP \times p^Gp$

Offspring

	Observed	Calculated	
P^Lp^G	34	33.2	df = 3
Pp^G	35	33.2	x^2 = 0.745
P^Lp	29	33.2	p = 0.7 – 0.95
p p	35	33.2	

TABLE V

P^Lp^G selfed

	Observed	Calculated	
P^LP^L	14	14.5	df = 2
P^Lp^G	30	29	x^2 = .054
p^Gp^G	14	14.5	p = .95 – .99

SUMMARY

A new allele, which we have designated as P^L, has been discovered in the purple series. This gene produces dark blue petals, dark purple at the base of the calyx, and a more uneven distribution of anthocyanin in the leaves than does its allele P.

LITERATURE CITED

(1) **Boye, C. L. and D. C. Rife. Genetic Studies of Coleus. Jour. Hered. 29: 55–60. 1938.**
(2) **Boye, C. L. An Allelic Series in Coleus. Jour. Genet. XLII: 191–196. 1941.**
(3) **Boye, C. L. Unpublished Doctor's dissertation, Ohio State University. 1941.**

THE OHIO JOURNAL OF SCIENCE

VOL. XLV SEPTEMBER, 1945 No. 5

UPPER PENNSYLVANIAN AND LOWER PERMIAN ROCK SECTION AT BLAINE HILL, BELMONT COUNTY, OHIO[1]

GEORGE W. WHITE,
The Ohio State University

The relocation of the National Highway, Ohio–U S. Route 40, in Belmont County has exposed many rock cuts in upper Pennsylvanian and lower Permian rocks from Morristown in the western part of the county to Blaine in the eastern part. These exposures have been studied as part of the investigation of the Monongahela formation by the Geological Survey of Ohio. The section exposed on the "Blaine Hill," (Fig. 1), 4 miles east of St. Clairsville, is of especial interest as it provides fresh outcrops of the upper part of the Conemaugh formation and of all of the Monongahela formation of the Pennsylvanian system and of most of the Washington formation and of the basal beds of the Greene formation of the Permian system. Its accessibility along a major highway makes a record and identification of the units of perhaps some general interest.

The section was measured by hand level in June, 1944, with the efficient aid of Mr. Richard E. Lee, field assistant during the 1944 field season. Dr. Aureal T. Cross, National Research Council Fellow, collected specimens from each of the coal units for study of micro-fossils, and his suggestions at certain points were helpful. Later in June Dr. Myron T. Sturgeon of the staff of the Geological Survey of Ohio reviewed the section with the writer, assisted in measuring a part of the Washington formation, and made extensive collections from the limestones and calcareous shales for paleontological study Dr. Sturgeon's advice and assistance were much appreciated. Dr. Wilber Stout, Director of the Geological Survey of Ohio, has generously given counsel and suggestions based on his unrivalled knowledge of the Coal Measures in Ohio. The elevation of the Pittsburgh coal is from the records of the State Highway Testing Laboratory through the courtesy of Mr. Harry Marshall.

A section along the old National Pike west of Blaine was measured by Stauffer and Schroyer,[2] but this section was measured along the old road, where exposures were slumped and overgrown and many details and several members were concealed. The rocks did not outcrop so boldly as to excite the interest and notice of the casual traveler along the road as is now the case. The new location is much higher on the hillside as far as the horizon of the Washington coal and somewhat lower through the horizons above the Washington coal. Several hundred yards separate the outcrop of some horizons on the new location from their position along the old road, and certain differences in thickness and character of some units are to be expected in comparing the two sections. The names of the members in the section are those used by the Geological Survey of Ohio.[3]

[1]Published by permission of the Director, Geological Survey of Ohio.
[2]Stauffer, C. R., and Schroyer, C. R., "The Dunkard Series in Ohio," *Geol. Surv. Ohio Bull.* *22*, pp. 48–49, 1920.
[3]Stout, W., "The Monongahela Series in Eastern Ohio," *Proc. W. Va. Acad. Science*, vol. 3, pp. 118–133, 1930.
Ibid., "Generalized Section of the Coal Bearing Rocks of Ohio," *Geol. Surv. Ohio Information Circular No. 2*, 1939.

Dr. M. T. Sturgeon, who collected samples for paleontological study in company with the writer and on other occasions, now has in preparation a report on his investigations of the approximately 70 limestone and calcareous shale units of the section. He informs the writer[4] that most of the strata so far studied are fossiliferous. He reports that ostracods, gastropods, and annelid worm tubes (*Spirorbus*) are the most abundant, but that fish remains and rare pelecypods are also present.

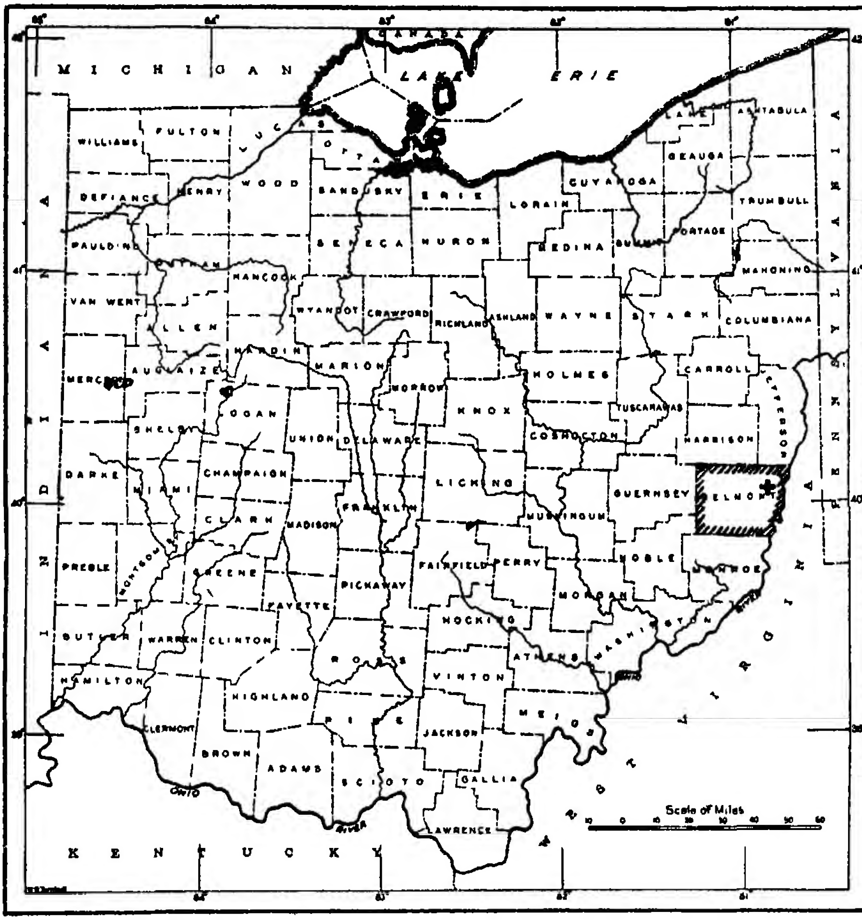

FIG. 1. Map of Ohio showing location of Belmont County and of Blaine Hill.

The rock section starts at road level at the bottom of the west side of the most westerly post on the south side of the viaduct at Blaine, in central-north Section 15, Pultney Township, Belmont County, and extends westward across the northwestern part of Section 15, and across the northeastern part of Section 21, Richland Township, to the sharp turn at the top of the ridge in southwestern Section 22 of the latter township. Comments on certain units are given after the section which follows by reference to the appropriate number.

[4]Sturgeon, M. T., personal communication, June 11, 1945.

ROCK SECTION AT BLAINE HILL, BELMONT COUNTY

			Thickness		Interval from base of Pittsburgh	
PERMIAN SYSTEM—DUNKARD SERIES						
GREENE FORMATION			Ft.	In.	Ft.	In.
163.	Shale, siliceous		1	0	470	3
162.	Coal, weathered, fair to good, *Jollytown "A,"* elevation 1,290± ft.		0	5	469	10
WASHINGTON FORMATION						
161.	Shale, gray, calcareous		0	8	469	2
160.	Limestone, gray; weathers to irregular fragments	*Upper Washington*	2	6	466	8
159.	Limestone, weathered; or shale, very calcareous	*Upper Washington*	6	11	459	9
158.	Shale, sandy, somewhat calcareous	*Upper Washington*	2	7	457	2
157.	Limestone, shaly, impure	*Upper Washington*	3	0	454	2
156.	Shale, calcareous		2	2	452	0
155.	Sandstone, medium-grained, micaceous, massive, ripple marked, exposed as extensive surface north of pavement at curve at Pullman's restaurant, *Hundred*		6	0	446	0
154.	Covered; along slope up National Road to crest of hill		27	3	418	9
153.	Limestone, weathered, irregular	*Middle Washington*	10	0	408	9
152.	Sandstone, buffish green, micaceous, calcareous, fine to medium-grained	*Middle Washington*	1	9	407	0
151.	Limestone, gray, nodular	*Middle Washington*	0	5	406	7
150.	Shale, calcareous	*Middle Washington*	1	10	404	9
149.	Limestone, gray, nodular	*Middle Washington*	0	8	404	1
148	Sandstone, greenish gray, micaceous, calcareous, massive to irregular	*Middle Washington*	6	4	397	9
147.	Sandstone, very irregular, shaly	*Middle Washington*	3	0	394	9
146.	Shale, siliceous	*Middle Washington*	2	5	392	4
145.	Shale, gray, calcareous	*Middle Washington*	1	0	391	4
144.	Limestone, shaly to marly, ferruginous, weathers rose pink, *Creston* horizon	*Middle Washington*	2	1	389	3
143.	Limestone, blue-gray, shaly; and shale, calcareous	*Middle Washington*	5	10	383	5
142.	Limestone, gray, marly	*Middle Washington*	3	0	380	5
141.	Limestone, weathered	*Middle Washington*	7	8	372	9
140.	Covered (*Lower Washington* limestone horizon)		35	2	337	7
139.	Sandstone, thin-bedded	*Lower Marietta*	5	0	332	7
138.	Sandstone and covered	*Lower Marietta*	10	7	322	0
137.	Coal blossom, *Washington*		3	6	318	6
136.	Covered		4	6	314	0
135.	Shale, calcareous; and limestone, nodular		5	6	308	6
134.	Limestone, weathered tan		5	8	302	10
133.	Shale, sandy, irregular		1	9	301	1
132.	Sandstone, shaly to thin-bedded; part cross-bedded.		7	2	293	11
131.	Shale, sandy; with ore nodules		3	4	290	7
130.	Sandstone, shaly		1	0	289	7
129.	Shale, sandy; with ore nodules		1	3	288	4
128.	Shale, clayey to siliceous; with ore nodules.		2	4	286	0
127.	Ore, irregular, weathered		0	3	285	9
126.	Clay shale, gray, micaceous.		1	3	284	6

			Ft.	In.	Ft.	In.
125.	Siderite, blue-gray, dense; single layer.		0	3	284	3
124.	Clay shale, gray		2	4	281	11
123.	Clay shale, with carbonaceous streaks		0	2	281	9
122.	Clay shale, gray, irregular fracture.		1	2	280	7
121.	Shale, coally below to carbonaceous above	*Waynesburg "A"*	0	10	279	9
120.	Limestone, dark; with carbonaceous streaks	*Waynesburg "A"*	0	2	279	7
119.	Clay shale, gray	*Waynesburg "A"*	0	3	279	4
118.	Shale, coally	*Waynesburg "A"*	0	4	279	0
117.	Limestone, blue-gray, dense, very hard; in several beds	*Mt. Morris*	2	10	276	2
116.	Shale, siliceous to sandy; with ore knots	*Mt. Morris*	5	10	270	4
115.	Limestone, gray, dense, hard	*Mt. Morris*	0	4	270	0
114.	Shale, with ore knots.	*Mt. Morris*	1	7	268	5
113.	Sandstone, massive		2	5	266	0
112.	Shale, silty		1	2	264	10
111	Sandstone, coarse; in two beds		1	9	263	1
110.	Shale, siliceous, fine-grained.		7	4	255	9
109.	Clay shale, carbonaceous		0	3	255	6
108.	Limestone, thin-bedded to shaly		0	7	254	11
107.	Limestone, blue-gray, dense, hard.		1	2	253	9
106.	Shale, siliceous to sandy		1	10	251	11
105.	Clay shale, gray.		4	0	247	11
104.	Clay shale, carbonaceous		1	0	246	11
103.	Limestone, gray-blue, hard, shaly	*Elm Grove*	1	5	245	6
102.	Shale, gray blue, calcareous	*Elm Grove*	0	9	244	9
101.	Limestone, gray, dense, micro-crystalline, fossiliferous; lower ½" is bone bed with fish teeth	*Elm Grove*	1	10	242	11
100.	Clay shale, with thin carbonaceous streaks	*Cassville*	1	0	241	11
99.	Shale, carbonaceous	*Cassville*	0	5	241	6
98.	Clay shale, gray	*Cassville*	0	5	241	1
97.	Clay shale, carbonaceous	*Cassville*	0	2	240	11
96.	Clay shale, gray, irregular fracture	*Cassville*	0	5	240	6

PENNSYLVANIAN SYSTEM

MONONGAHELA FORMATION

			Ft.	In.	Ft.	In.
95.	Shale, bony to coally	*Waynesburg*	0	3	240	3
94.	Coal, blocky, banded	*Waynesburg*	1	7	238	8
93.	Shale, dark, carbonaceous	*Waynesburg*	0	¼	238	7¾
92.	Coal, blocky, banded	*Waynesburg*	1	6	237	1¾
91.	Shale, carbonaceous	*Waynesburg*	0	¼	237	1½
90.	Coal, bright	*Waynesburg*	0	2½	236	11
89.	Clay shale, somewhat carbonaceous		0	2	236	9
88.	Clay, very impure		2	0	234	9
87.	Shale, siliceous to sandy.		4	5	230	4
86.	Sandstone, shaly; with shale streaks; contains a few ore knots	*Gilboy*	3	4	227	0
85.	Shale, sandy	*Gilboy*	13	5	213	7
84.	Sandstone, fine-grained, shaly	*Gilboy*	1	9	211	10
83.	Shale, blue-gray, silty to siliceous		11	6	200	4

			Ft.	In.	Ft	In.
82.	Coal, bony, grading upward to bone shale		1	2	199	2
81.	Coal, blocky		0	3	198	11
80.	Shale, carbonaceous		0	2	198	9
79.	Limestone, tannish gray; with thin carbon shreds		0	4	198	5
78.	Shale, black, very hard, carbonaceous, calcareous, (black-band?)	*Uniontown*	0	5	198	0
77.	Coal, bony		0	1½	197	10½
76.	Shale, black, carbonaceous		0	2½	197	8
75	Coal, bony		0	8	197	0
74.	Shale, black, very hard, calcareous, ferruginous; contains ostracods		0	4	196	8
73.	Shale, gray		4	3	192	5
72.	Limestone, gray, shaly		2	2	190	3
71.	Limestone, gray, marly		4	3	186	0
70.	Limestone, "cemented breccia"	*Uniontown*	1	5	184	7
69.	Limestone, shaly to marly		1	1	183	6
68.	Limestone, composed of cemented nodules and fragments, fossiliferous		1	3	182	3
67.	Shale, gray-green, calcareous and siliceous; lower part not well exposed		17	0	165	3
66.	Limestone, gray, dense; upper part not well exposed		6	11	158	4
65.	Shale, serpentine green	*Arnoldsburg*	3	5	154	11
64.	Limestone, irregularly bedded		5	6	149	5
63.	Limestone, nodular, weathered		2	10	146	7
62	Shale, green, siliceous	*Fulton*	1	10	144	9
61.	Shale, gray-green, sandy		2	3	142	6
60	Limestone, shaly; with some beds to 6"		6	6	136	0
59.	Limestone, shaly, marly		7	9	128	3
58	Limestone, gray, "flint clay" fracture		5	6	122	9
57	Limestone, gray, laminated, weathers platy	*Benwood*	3	9	119	0
56.	Limestone, dark gray, argillaceous, "flint clay" fracture		21	0	98	0
55.	Limestone, gray-blue, shaly and marly		5	6	92	6
54.	Shale, gray, carbonaceous		1	6	91	0
53.	Coal, shaly (or shale, coally)		1	3	89	9
52.	Coal, blocky		2	½	87	8½
51.	Shale, coally, fine banded; with macerated plant fragments and mica flakes	*Meigs Creek*	0	5½	87	3
50.	Coal, bright, banded		0	10	86	5
49.	Shale, bony and coally		0	3	86	2
48.	Clay shale, carbonaceous		0	2	86	0
47.	Clay shale, gray, calcareous		1	6	84	6
46.	Sandstone, gray, micaceous, calcareous		1	1	83	5
45.	Limestone, weathered buff; with irregular shale partings, *Sewickley*		9	6	73	11
44.	Covered; indication of carbonaceous shale blossom, *Fishpot*		11	1	62	10

			Ft.	In.	Ft.	In.
43.	Limestone, in 1" to 2" beds	Fishpot	5	7	57	3
42.	Limestone, gray-blue, dense	Fishpot	10	9	46	6
41.	Limestone, weathers tan, single bed	Fishpot	1	3	45	3
40.	Shale, gray, calcareous	Fishpot	2	2	43	1
39.	Limestone, thin-bedded	Fishpot	0	3	42	10
38.	Limestone, gray, dense	Fishpot	1	8	41	2
37.	Shale, gray, calcareous	Fishpot	0	10	40	4
36.	Limestone, dove gray, microbanded, cherty fracture, weathers white	Fishpot	1	6	38	10
35.	Limestone, tan, shaly	Fishpot	0	3	38	7
34.	Limestone, tan, dense; a few calcite crystals	Fishpot	1	7	37	0
33.	Shale, dark gray, calcareous	Fishpot	0	2	36	10
32.	Limestone, gray-blue, "cemented breccia"	Fishpot	1	1	35	9
31.	Shale, gray, calcareous	Fishpot	0	10	34	11
30.	Limestone, gray, irregular, dense, marly	Fishpot	3	7	31	4
29.	Shale, gray, calcareous		2	11	28	5
28.	Coal, bony and shaly, *Pomeroy* (*Redstone*)		0	4	28	1
27.	Shale, gray; with carbonaceous streaks		1	10	26	3
26.	Limestone, gray, dense, massive, conchoidal fracture	Redstone	2	4	23	11
25.	Limestone, gray-blue, marly; with shale streaks	Redstone	8	9	15	2
24.	Shale, gray, calcareous	Redstone	1	4	13	10
23.	Limestone, gray-blue, dense, irregular	Redstone	1	9	12	1
22	Shale, gray, calcareous		2	0	10	1
21.	Shale, gray, calcareous, with carbonaceous streaks		2	2	7	11
20.	Coal, bony; with shale interbedded ("roof")	Pittsburgh	1	5	6	6
19.	Shale, black, bony ("roof")	Pittsburgh	0	5	6	1
18.	Clay shale, gray; "draw slate"	Pittsburgh	0	4	5	9
17.	Coal, bony, canneloid	Pittsburgh	0	2½	5	6½
16	Coal, very hard, blocky ("breast")	Pittsburgh	1	10	3	8½
15.	Shale, carbonaceous ("breast")	Pittsburgh	0	½	3	8
14.	Coal, blocky, hard ("breast")	Pittsburgh	0	3	3	5
13.	Shale, carbonaceous	Pittsburgh	0	½	3	4½
12.	Coal, with shaly streaks; "bearing in"	Pittsburgh	0	6	2	10½
11.	Shale, carbonaceous	Pittsburgh	0	½	2	10
10.	Coal, blocky ("brick")	Pittsburgh	0	5½	2	4½
9.	Shale parting ("brick")	Pittsburgh	0	¼	2	4¼
8.	Coal, blocky ("brick")	Pittsburgh	1	½	1	3¾
7.	Shale, carbonaceous	Pittsburgh	0	¼	1	3½
6.	Coal, blocky; "bottom"	Pittsburgh	1	½	0	3
5.	Coal, shaly and bony	Pittsburgh	0	3	0	0

Elevation base of *Pittsburgh* coal, 819.5 ft.

CONEMAUGH FORMATION

		Ft.	In.
4.	Clay shale, carbonaceous	0	3
3.	Shale, sandy, ferruginous	0	8
2.	Clay shale, gray	5	2
1.	Covered; and limestone, fossiliferous, *Upper Pittsburgh*	5	4

1. Approximately 100 feet of upper Conemaugh strata, mainly Bellaire sandstone, are exposed in the cliff beneath the viaduct but these strata are not included.

18. The "draw slate" is somewhat thinner than is usual in Belmont County.

28. The Pomeroy coal is better exposed just south of the main highway in a side road. It is thinner than is usual in Belmont County.

44. The only covered part of the Monongahela section occurs here where the road crosses a small ravine on a fill.

64–72. The distinction between the Arnoldsburg and Uniontown limestones is not always clear in the absence of the Arnoldsburg coal, which is not known to occur in Ohio;[5] unless well defined sandy beds intervene.[6]

74–82. The Uniontown coal is exposed at road level across the highway from the highway park, a few feet lower than the pump in the park. Of special interest is the limestone parting in the coal.

90–95. The Waynesburg coal is exposed at the top of the cut opposite the pump at the highway park. The section from the Uniontown coal to above the Waynesburg is exposed in the vertical cliff and well shown is the transition from the calcareous character of the Monongahela below the Uniontown to the clastic character above it. The Waynesburg coal is at road level opposite the upper part of the park. It has been mined in the hollow south of the road.

101–103. The Elm Grove limestone is exposed at road level opposite the upper part of the park. The contact between 102 and 103 appears to be an unconformity.

114–117. The limestone strata at this horizon constitute the Mt Morris member. From St. Clairsville westward to Morristown dark, dirty, greenish gray, ferruginous, argillaceous limestone is well developed at this horizon The member is present in Pultney, Richland, and Union townships of Belmont County, and probably extends beyond these It is present in Jefferson County;[7] but in much reduced thickness. At Blaine Hill the Mt. Morris limestone is less ferruginous and does not have the dirty greenish gray color which characterizes the member further west, especially near Morristown in central Union Township

120. The limestone parting in the Waynesburg "A" coal is noteworthy.

137. The Washington coal is better exposed 50 yards south of the National Road on a road at the east boundary of a cemetery. Its thickness in this section is less than in much of Belmont County.

141–153. The Middle Washington limestone is prominently exposed on the north side of the road in the cut west of the Bellaire Road fork. The Creston ferruginous member, 144, is much better developed as an iron ore 5 miles to the northeast, where it was formerly mined in southeast Section 1, Pease Township.

154–163. Because of the lateral extent of the covered interval 154, the correlation of the members above is less certain than could be desired.

156–163. The calcareous units here called Upper Washington are exposed in the cut at the top of the slope on the south side of the road, opposite Pullman's restaurant. The beds are more or less weathered. They are well and more freshly exposed in a cut one-fourth mile west along the road at a fruit stand on the south side of the road, in southeast Section 28, Richland Township Here the Upper Washington limestone is fossiliferous; the Jollytown "A" coal 6 inches thick, overlain by 16 feet of sandy shale and thin-bedded Jollytown sandstone.

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[5]Stout, W., *op. cit.*, 1939.

[6]Lamborn, R. E., "Geology of Jefferson County," *Geol. Surv. Ohio Bull 35*, pp 244–246, 1930.

[7]Lamborn, *ibid.*, p. 259.

THE DESMIDS OF THE WEST END OF LAKE ERIE[1,2]

CLARENCE E. TAFT

INTRODUCTION

For several years the writer has had the opportunity to study the desmids of the Island Region of the west end of Lake Erie. First in 1933, and later while a member of the staff of the Franz Theodore Stone Laboratory on Gibraltar Island in Put-in-Bay Harbor during the summers of 1938, 1940, and 1941. Collections made from the open lake, shore margins, and from ponds and beach pools on the Islands were augmented during the interim from 1933 to 1938 by collections made by Tiffany during his work on "The plankton algae of the west end of Lake Erie" (1934) and "The filamentous algae of the west end of Lake Erie" (1937). The writer gratefully acknowledges these collections, as well as many collections placed at his disposal by members of the fresh-water algae classes at the Stone Laboratory.

The writer hopes that this report, the latest in a series on the algae of the region will be not only of taxonomic interest, but helpful to the student of aquatic biology. For the benefit of the latter the paper has been prepared in somewhat greater detail than would otherwise be necessary.

Two groups remain to be reported. They are the Dinophyceae (which has been only superficially worked) and the Bacillariophyceae. Of the two classes, the representatives of the latter are far more numerous, and at times constitute an important bulk of the plankton. It is hoped that in the near future this group may receive the attention that its importance deserves.

DESMID HABITATS OF THE REGION

The survey was limited to a portion of an area generally known as the Island Region of the west end of Lake Erie and is shown on the accompanying map. Although some collections from islands north of this area were examined, they have not been reported.

South Bass Island, on which is located the town of Put-in-Bay, is the largest of the Bass Islands group, and is of little interest algologically beyond the protected inlets located around Put-in-Bay Harbor. There are three of these inlets having semi-pond characteristics and known as Terwilligers Pond, Squaw Harbor, and Hatchery Bay. These are protected considerably from northeast storms by Gibraltar Island and from northwest and southwest storms by the land adjoining the harbor. This protection, along with shallow water, makes them excellent habitats for the higher aquatics. In general they contribute interesting desmid collections, and are especially good for species of *Cosmarium*.

Middle Bass Island, which lies approximately one mile due north of South Bass, contains three shallow ponds, referred to in this report as Wehrle, Fisher, and Haunk. These ponds have mud bottoms and are choked to such an extent with aquatics that, during low water levels, they become veritable marshes whose weedy margins afford the quiet water desirable for desmid collecting.

North Bass Island, slightly more than one mile north of Middle Bass, contains two large ponds or marshes, their classification dependent upon the lake level.

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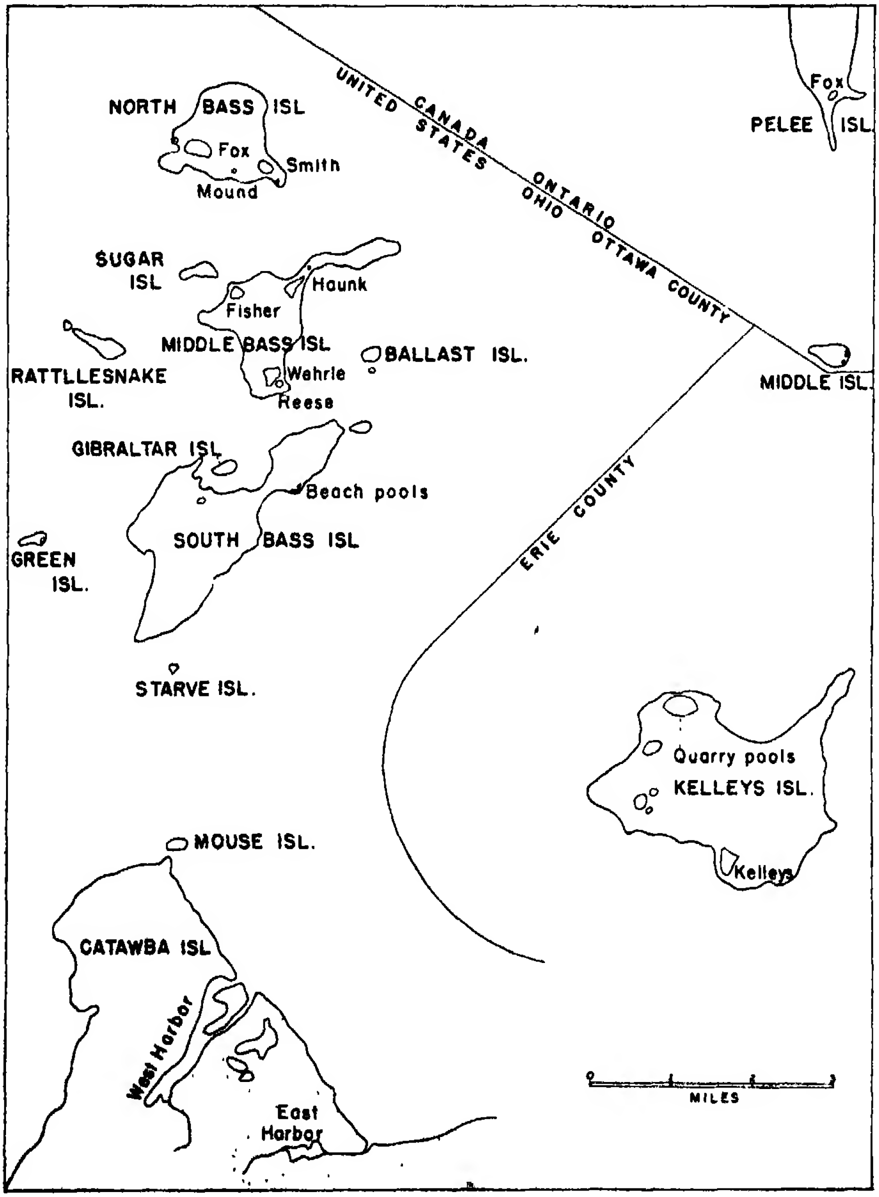
[1]Paper from the Department of Botany, The Ohio State University, No. 487, and the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio.

[2]Financial aid for the publication of the plates was granted by the Franz Theodore Stone Laboratory through the Director, Dr. Thomas H. Langlois. For this, as well as the many Laboratory facilities placed at his disposal which made possible the collections, the writer expresses his thanks.

Fox Pond is a natural depression, while Smith Pond is an abandoned carp propagation pond. A third, known as Mound Pond, is located near the south shore dock and exists only during the wetter seasons. A few beach pools in addition to these three ponds constitute the desmid habitats of the Island.

Kelleys Island lies approximately six miles S. E. of South Bass. Although there are some swamp areas, the unique habitats of the Island are the numerous



Map of the Islands Region of the Western End of Lake Erie.
(Adapted from the Put-in-Bay and Kelleys Island Quadrangles of the United States Geological Survey.)

abandoned quarries. The water in these varies from a few inches in depth to forty feet. The desmids, although never abundant in these quarries, appear quite frequently in the bottom ooze of the shallow water.

Pelee Island in Canadian water offers several varied habitats such as drainage ditches, abandoned quarries, canals, and Fox's Marsh; the latter, an extensive peaty area almost entirely choked with aquatic macrophytes, being the most interesting.

East and West Harbors are on the east shore of the mainland peninsula of Catawba Island which lies directly south of South Bass. These are the largest cônfined bodies of water in the region (opening into Lake Erie only through narrow inlets) and with their weedy margins may be considered as shallow lakes. East Harbor, being more readily accessible because of regular field trips scheduled from the Laboratory, has received more attention than West Harbor. Aside from the regularly traveled channels, the water is shallow and at times one finds it nearly impossible to maneuver a boat because of the abundance of submerged and floating aquatics. Collecting becomes merely a matter of rinsing the desmids from the leaves and stems of these macrophytes into suitable containers.

Of less general interest and importance are the habitats existant on the smaller islands of Starve, Green, Rattlesnake, Sugar, Ballast, Gibraltar, and Middle. The latter, which is due south of Pelee, is in Canadian water. These habitats are mostly temporary and may best be described as spray or beach pools whose existence depends on the frequency and severity of storms.

TABLE I

Locality	Genera	Species	Varieties
Terwilligers Pond	1	1	.
Hatchery Bay	2	5	2
Squaw Harbor	5	21	10
Wehrle Pond	4	11	9
Haunk Pond	4	15	7
Fisher Pond	3	8	7
Smith Pond	4	11	2
Fox Marsh	3	2	1
Mound Pond	1	1	..
Kelleys Island	6	24	12
Pelee Island	5	13	11
East and West Harbors	9	28	9
Other Habitats	2	7	6

THE RELATIVE ABUNDANCE OF DESMIDS

Prior to the completion of this survey, 460 species, varieties and forms of algae distributed in 141 genera were listed for the region. Tiffany (1934, 1937), Taft (1942). With the completion of the present survey, the number is increased to 599 species, varieties and forms distributed in 154 genera. This number does not include the unverified desmid reports by earlier workers. The desmids account for 139 of the species total, or approximately 23%. While these figures do not indicate a rich desmid region, they show that relatively the desmids are an important constituent of the algal flora. An entirely different picture is presented when an analysis of the genera is made. Of the 154 genera known from the region, only 13, or 8.4%, are desmid genera. The result of this descrepancy is that one finds species representing one, two, or at the most, three genera predominant in the collections. Representatives of genera other than *Closterium*, *Cosmarium*, and *Staurastrum* are not common. The explanation of this phenomena is not entirely

clear although to one familiar with the region and with desmid distribution the data are not exactly irrelevant. Desmids are usually encountered in numbers (both genera and species) only in sandy or boggy regions where the waters are acid. Limestone regions with their subsequent hard water, are notoriously poor in the desmid flora they support. Consequently the Island Region of the west end of Lake Erie, with its alkaline waters (pH 7 to pH 10) should not be expected to yield a rich desmid flora. It is this that makes the large number of species present an interesting problem in distribution.

Table I summarizes the relative abundance of the genera, species, and varieties of desmids in the various locations from which collections were made.

PREVIOUS REPORTS ON LAKE ERIE DESMIDS

There have been no reports dealing exclusively with the desmids of the region. Papers which have included them along with other algae as well as vascular plants are those of Pieters (1901), Snow (1902) and Chandler (1940). As Tiffany (1934, 1937) did not include them, this is the first attempt at a comprehensive study of the group.

Unfortunately many of the previously reported species have not reappeared in the writers collections, although in some instances varieties of the species have been collected. This may partially be due to the fact that a number of the earlier reports were from the Portage River, which lies outside the arbitrary limits set for this survey. These unverified records are included in the following list, but are not described or figured.

Closterium acutum var. *linea* Klebs.
(*Closterium pronum* Bréb. var. *linea* Klebs, Pieters, The plants of western Lake Erie, 1901, p. 79.)
Closterium lineatum Ehren.
Cosmarium angulosum var *concinnum* (Rab.) W. & G. S. West.
(*Cosmarium meneghinii* var. *concinnum* Rab., Snow, The plankton algae of Lake Erie, 1902, p. 392.)
Cosmarium brébissonii Menegh.
Cosmarium connatum (Bréb.) DeBary.
(*Dysphinctium connatum* (Bréb.) DeBary, Pieters, The plants of western Lake Erie, 1901, p. 79).
Cosmarium crenatum Ralfs.
Cosmarium depressum Lund.
Cosmarium euastroides N.
Cosmarium kjellmanii Wille
Cosmarium margaritiferum Menegh.
Cosmarium moniliforme Ralfs.
Cosmarium nitidulum De Not.
Cosmarium ornatum Ralfs.
Cosmarium punctulatum Bréb.
Cosmarium pygmaeum Archer.
Cosmarium ralfsii (Bréb.) Lund.
(*Pleurotaenopsis ralfsii* (Bréb.) Lund., Pieters, The plants of western Lake Erie, 1901, p. 79.)
Cosmarium reniforme var. *compressum* Nordst.
Cosmarium tetraophthalmum Kuetz.
Cosmarium tinctum Ralfs.
Euastrum binale Ralfs.
Euastrum elegans Kuetz.
Euastrum verrucosum Ehren.
Staurastrum avicula Bréb.
Staurastrum brebissonii Archer.
Staurastrum dejectum Bréb.
Staurastrum dilatum Ehren.
Staurastrum gracile Ralfs.
Staurastrum oblongum N.
Staurastrum teliferum Ralfs.
Xanthidium antilopeum Kuetz.
Hyalotheca dissiliens Bréb.
Onychonema laeve Nordst. var. *minus* Borge.
Onychonema filiforme (Ehren.) R. & B.
(*Sphaerozosma filiforme* Rab., Snow, The plankton algae of Lake Erie, 1902, p. 392.)

THE DESMIDS

The name "desmids" as used in this report assumes the original meaning and applies to the organisms now grouped in two Families, the Mesotaeniaceae and the Desmidiaceae within the Order *Zygnematales* of the Class *Chlorophyceae*. In general they are unicellular plants of varied form, symmetrical in three planes at right angles to each other. Most of the members of the *Desmidiaceae* are divided into two equal semi-cells by a more or less prominent median constriction. Those of the *Mesotaeniaceae*, while never distinctly constricted, usually have the protoplasm and the plastids divided into two equal halves. The members of the *Desmidiaceae* are further separated from the *Mesotaeniaceae* by having their walls composed of two over-lapping halves instead of being continuous, and with a differentiated outer layer with pores.

Because of the general availability of standard references concerning this group, a complete taxonomic treatment has not been attempted by the writer. However, the problems of the student of aquatic biology have been considered and the report prepared accordingly. A key to the genera, as well as brief descriptions of the species, has been included. Illustrations are from the writer's original camera lucida drawings.

Keys to the species, if they attempt to give the necessary differentiating characters, become exceedingly complex, and subsequently defeat their purpose of simplification. Therefore such keys have been excluded. The student, after determining the genus, should work by constant reference to descriptions and figures. The identification of a species is best attempted from a number of individuals which will give the variations, instead of from what may turn out to be a non-typical individual.

NEW SPECIES AND VARIETIES

Seven species and seven varieties have been named and described, while one form has been given varietal rank.

Closterium eriense sp. nov.
Euastrum ohioense sp. nov.
Cosmarium eriense sp. nov.
Cosmarium franzstonii sp. nov.
Cosmarium impressulum var. *suborthogona* (W. & G. S. West) Comb. nov.
Cosmarium nitidulum var. *pseudovalidum* var. nov.
Cosmarium reniforme var. *seminudum* var. nov.
Cosmarium subnudiceps var. *granulatum* var. nov.
Cosmarium subraciborskii sp. nov.
Cosmarium viride var. *compressum* var. nov.
Staurastrum biarcuus sp. nov.
Staurastrum bicoronatum var. *tridentatum* var. nov.
Staurastrum brevispinum var. *canadense* var. nov.
Staurastrum peleii sp. nov.
Staurastrum polytrichum Perty var. *ornatum* var. nov.

KEY TO THE GENERA

1. Filamentous 11
1. Unicellular (sometimes in readily disassociating filaments) 2
    2. Cell length not more than twice the breadth 8
    2. Cell length twice the breadth, or more 3
3. Without a median constriction 4
3. With a more or less distinct median constriction 7
    4. Chloroplasts ribbon-like, axial, straight; cells in readily disassociating filaments, **Gonatozygon**
    4. Chloroplasts not ribbon-like 5
5. Chloroplasts substellate, 2 per cell; cells sometimes slightly curved .... **Cylindrocystis**
5. Chloroplasts longitudinally ridged, two per cell 6
    6. Cells straight, nearly cylindrical, apices broadly rounded .... **Penium**
    6. Cells usually strongly curved, apices attenuated .... **Closterium**

7. Median constriction indistinct; cells nearly cylindrical, apices broadly rounded; semi-cells not inflated at the base .... **Penium**
7. Median constriction distinct; cells cylindrical, apices broadly rounded to truncate; base of semi-cell inflated, not plicate .... **Pleurotaenium**
   8. Cells compressed 9
   8. Cells radially symmetrical, if compressed then with apical angles produced into divergent processes .... **Staurastrum**
9. Margins of semi-cells variously lobed, apex sometimes incised 10
9. Margins of semi-cells seldom lobed (sometimes undulate or crenate), sometimes with spines; apex not incised .... **Cosmarium**
   10. Lateral lobes separated by shallow incisions, apex usually deeply incised; cell wall variously ornamented .... **Euastrum**
   10. Lateral lobes separated by deep incisions, apex with shallow incision, or retuse, **Micrasterias**
11. Cells united by special apical processes, compressed; filaments not twisted. **Sphaerozosma**
11. Cells not united by apical processes 12
   12. Cells triangular in vertical view, median constriction distinct; filaments twisted, **Desmidium**
   12. Cells not triangular in vertical view 13
13. Cells circular in vertical view, median constriction indistinct .... **Hyalotheca**
13. Cells elliptical in vertical view, median constriction deep .... **Spondylosium**

SPECIES LIST

Gonatozygon De Bary 1856

Cells cylindrical, length 10–20 times the diameter, not constricted, apices truncate and slightly inflated, in filaments which readily disassociate. Chloroplasts two, axial, narrow and undulate, pyrenoids numerous.

1. *Gonatozygon kinahani* (Arch.) Rab. (Pl. I, Fig. 1) L. 135–195μ, w. 11–12μ. Squaw Harbor.
2. *Gonatozygon monotaenium* De Bary (Pl. I, Fig. 2) L. 101–190μ, w. 9–10μ. Kelleys Isl. quarry pools.

Cylindrocystis Menegh. 1838

Cells cylindrical, sometimes slightly curved, length varying to 3½ times the diameter, unconstricted, apices rounded, embedded in mucilage; with two axial, stellate chloroplasts; pyrenoids large, one in each chloroplast.

1. *Cylindrocystis brebissonii* Menegh. var. *minor* W. & G. S. West (Pl. I, Fig. 3) L. up to 42μ, w. 12–13μ. Partially submerged rocks, Gibraltar.

Penium Bréb. 1844

Cells cylindrical to fusiform, with or without a slight median constriction, apices rounded or subtruncate; chloroplasts one or two in each semicell, each a central mass with radiating longitudinal plates, plates entire along the margins; pyrenoids axial, one or more; cell wall with pores.

1. *Penium margaritaceum* (Ehren.) Bréb. (Pl. I, Fig. 4). L. 115–184μ, w. 21–23μ. East Harbor, Kelleys Isl., Manila Bay.

Pleurotaenium Naeg. 1849

Cells straight, elongated, cylindrical, constricted, semicells with a non-plicate, inflated base; apex with or without tubercles; chloroplasts numerous, parietal, longitudinal bands.

1. *Pleurotaenium ehrenbergii* (Breb.) De Bary (Pl. I, Figs. 5, 6). L. 270–520μ, w. at base 27–30μ, w. at middle of semicell 25–35μ, w. at apex 16–18μ, isth. 21–23μ. Pelee.

   Many individuals showed a distinct shortening and tumidness of the semicells, but there were all gradations between these and the typical forms.
2. *Pleurotaenium trabecula* (Ehren.) Naeg. (Pl. I, Fig. 7). L. 360–580μ, w. at base 26–35μ, w. at apex 20–23μ. Wehrle, Fisher, Squaw Harbor.

Closterium Nitzsch 1817

Cells elongate, more or less attenuate, slightly curved to strongly lunate, unconstricted; ends of cells rounded, truncate or sharply pointed; cell wall smooth or striate, colorless to brown;

one axial chloroplast per semicell, each with longitudinal, radiating ridges; pyrenoids few to many, axial or scattered; each end of the cell with a vacuole containing moving granules of calcium sulphate.

1. *Closterium acerosum* (Schrank) Ehren. (Pl. I, Fig. 8). Cell wall smooth, colorless, often becoming yellow when old; chloroplast with 14–16 ridges and an axial series of about 10 pyrenoids. L. 340–475μ, w. 40–60μ. Squaw Harbor, Hatchery Bay, East Harbor.
2. *Closterium calosporum* Wittr. (Pl. I, Fig. 9). Cell wall smooth and colorless. L. 160μ, w. 13μ, zygospore about 32μ. Kelleys Isl.

   This species is very similar to *Cl. dianae* but the spore is distinctive.
3. *Closterium dianae* Ehren. (Pl. I, Fig. 10). Cell wall smooth, very pale yellow; chloroplast with about 4 ridges and 3–4 pyrenoids. L. 147–160μ, w. 13–14μ. Kelleys Isl.
4. *Closterium eboracense* (Ehren.) Turner (Pl. I, Fig. 11). Cell wall smooth and colorless; chloroplasts with about eight ridges and 4 pyrenoids. L. 220μ, w. 47μ. Squaw Harbor.
5. *Closterium ehrenbergii* Menegh. (No figure). Cell wall smooth and colorless; chloroplasts with 10–12 ridges and numerous scattered pyrenoids. L. 420–590μ, w. 80–101μ. Wehrle, Fisher, Haunk, Terwilliger's, East Harbor, Fox.
6. **Closterium eriense** Taft n. sp. (Pl. I, Fig. 12). Cells of medium size, seven times longer than broad, strongly curved (almost 180 degrees of arc), inner margin concave, not tumid, gradually attenuated to broadly rounded apices; cell wall smooth and very light yellow; chloroplasts? L. 215μ, w. 30μ, w. of apices 10μ. Squaw Harbor.

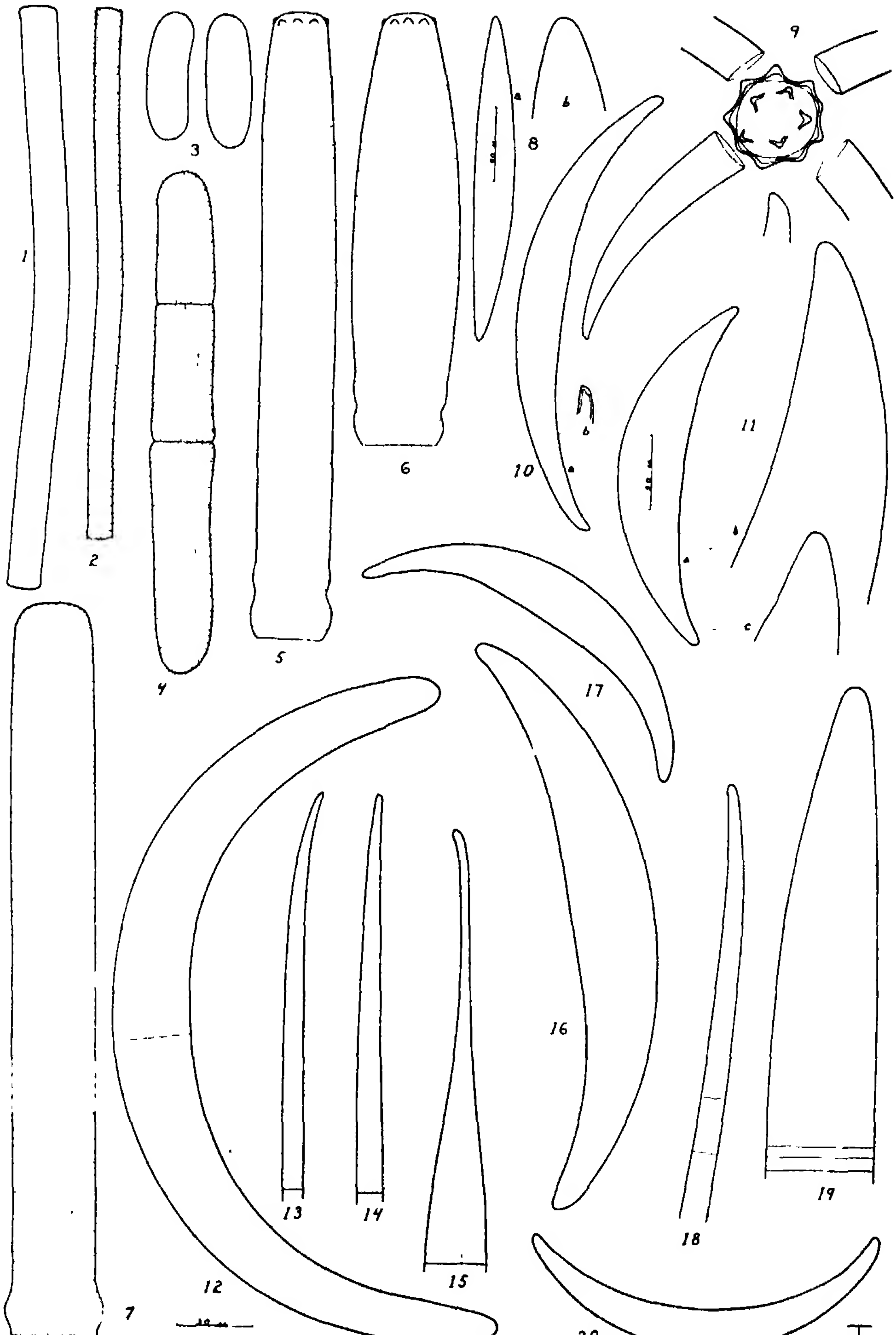
   Cl. mediocre, cellulis diametro 7 plo longioribus, ventre concavo, non distincte tumido, gradatim attenuatis apicibus versus, apicibus rotundatis; membrana glabra, luteola. Long. 215μ, lat. 30μ, lat. apic. 10μ.

   Although this must stand at the present as an incompletely described species because of the advanced decomposition of the chloroplasts when collected, it differs sufficiently to be given specific rank. Its greater size and the broadly rounded apices separate it from *Cl. parvulum* var. *angustum* W. & G. S. West. It is larger and less curved than *Cl. cynthia* var. *curvatissimum* W. & G. S. West.
7. *Closterium gracile* Bréb. (Pl. I, Fig. 13). Cell wall smooth and colorless; chloroplasts with about 6 pyrenoids. L. 211μ, w. 7μ. East Harbor.
8. *Closterium idiosporum* W. & G. S. West (Pl. I, Fig. 14). Cell wall smooth and colorless; chloroplasts faintly 4-ridged, with about 5 pyrenoids. L. 197–232μ, w. 9–10μ. Wehrle.
9. *Closterium kützingii* Bréb. (Pl. I, Fig. 15). Cell wall finely striate (about 12 striae per 10μ), becoming dark yellow when old; chloroplasts with about 4 ridges and 6 pyrenoids. L. 273–380μ, w. 20μ. Pelee.
10. *Closterium leibleinii* Kuetz. (Pl. I, Fig. 17). Cell wall smooth and colorless, sometimes very light yellow; chloroplasts with about 6 ridges and 3 pyrenoids. L. 115–121μ, w. 18–21μ. Haunk, Hatchery Bay, East Harbor.

    This species is variable as to size and curvature, especially the latter.
11. *Closterium lunula* (Muell.) Nitz. var. *coloratum* Klebs. forma? (Pl. I, Fig. 19). Cells quite large, between 7–10 times longer than broad, inner wall straight, outer wall broadly convex; apices broadly rounded; cell wall finely striate (10 striae per 10μ), yellow brown; chloroplasts with 10–12 ridges and numerous scattered pyrenoids. L. 330–375μ, w. 37–44μ. Squaw Harbor.

EXPLANATION OF PLATE I

Fig. 1. *Gonatozygon kinahani*. Fig. 2. *Gonatozygon monotaenium*. Fig. 3. *Cylindrocystis brebissonii* var. *minor*. Straight and curved cells. Fig. 4. *Penium margaritaceum*. Figs. 5, 6. *Pleurotaenium ehrenbergii*. Fig. 7. *Pleurotaenium trabecula*. Fig. 8a, b. *Closterium acerosum*. 8a, outline of cell; 8b, apex. Fig. 9. *Closterium calosporum*, with zygospore. Fig. 10a, b. *Closterium dianae*. 10a, outline of cell; 10b, detail of apex. Fig. 11a, b, c. *Closterium eboracense*. 11a, outline of cell; 11b, semicell; 11c, apex. Fig. 12. *Closterium eriense*. n. sp. Fig. 13. *Closterium gracile*. Semicell. Fig. 14. *Closterium* idiosporum. Semicell. Fig. 15. *Closterium kützingii*. Semicell. Fig. 16. *Closterium moniliferum*. Fig. 17. *Closterium leibleinii*. Fig. 18. *Closterium macilentum*. Fig. 19. *Closterium lunula* var. *coloratum* forma? Fig. 20. *Closterium parvulum*.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As this form is only one-half or one-third as broad as *Cl. lunula* var. *coloratum* there is some doubt as to its correct systematic position. Because of the close resemblance in regard to other characters, it will be left as a form of the variety *coloratum* Klebs.

12. *Closterium macilentum* Breb. (Pl. I, Fig. 18). Cell wall smooth and colorless (very faintly yellow in old specimens); chloroplasts with 8–10 pyrenoids. L. 270μ, w. 7μ. Smith.
13. *Closterium moniliferum* (Bory) Ehren. (Pl. I, Fig. 16). Cell wall smooth and colorless; chloroplasts with about 6 ridges and 5–6 axial pyrenoids. L. 204–310μ, w. 27–53μ. Fisher, Smith, Squaw Harbor, Hatchery Bay, East Harbor.
14. *Closterium parvulum* Naeg. (Pl. I, Fig. 20). Cell wall smooth and colorless; chloroplasts with 5–6 ridges and about 4 pyrenoids. L. 110–119μ, w. 13–18μ. Wehrle, Smith, Fox, Squaw Harbor.
15. *Closterium parvulum* var. *angustum* W. & G. S. West (Pl. II, Fig. 1). Cells much narrower and usually shorter than in the species, curvature greater; otherwise similar. L. 96–121μ, w. 5–7μ. Hatchery Bay, Kelleys Isl., East Harbor.
16. *Closterium praelongum* Bréb. (Pl. II, Fig. 2). Cell wall nearly colorless to yellow, appearing smooth (Krieger, 1935, reports 15 striae per 10μ when the wall is examined with oil immersion lens), chloroplasts with about 5 ridges and 10 pyrenoids. L. 860μ, w. 24μ. Pelee.
17. *Closterium praelongum* var. *brevius?* Nordst. (Pl. II, Fig. 3). Similar to the species but with smaller dimensions. L. 365–410μ, w. 18μ. Fisher.

    The specimens were intermediate in size between the species proper and the variety *brevius*. They have been assigned to the variety on the basis of the ratio of the axes.
18. *Closterium pritchardianum* Arch. (Pl. II, Fig. 4). Cell wall finely striate (9–10 striae per 10μ), striae composed of fine punctae, often subspiral, color yellow to red-brown; chloroplasts with 6–8 ridges and about 8 axial pyrenoids. L. 334–530μ, w. 21–37μ. Haunk, Fisher, Mound, Squaw Harbor, Hatchery Bay.
19. *Closterium subulatum* (Kuetz.) Breb. (Pl. II, Fig. 5). Cell wall smooth and colorless; chloroplasts with 3–4 pyrenoids. L. 128–188μ, w. 7–10μ. Fisher, Smith.
20. *Closterium venus* Kuetz. (Pl. II, Fig. 6). Cell wall smooth and colorless; chloroplasts ridged, with 2 (sometimes 3) pyrenoids. L. 76–85μ, w. 9–14μ. Haunk.
21. *Closterium venus* var. *incurvum* (Bréb.) Krieger (Pl. II, Fig. 7). Cell wall smooth and colorless, rarely yellowish when old; chloroplast with 3–4 pyrenoids. L. 39–66μ, w. 7–12u. Haunk, Smith, Squaw Harbor, East Harbor.

Euastrum Ehren. 1832

Cells variable in size, longer than broad, sometimes about as broad as long, strongly compressed, deeply constricted, sinus linear; semicells usually pyramidate, lateral margins variously lobed, center of semicell with one or more protuberances, apex usually truncate with an incision

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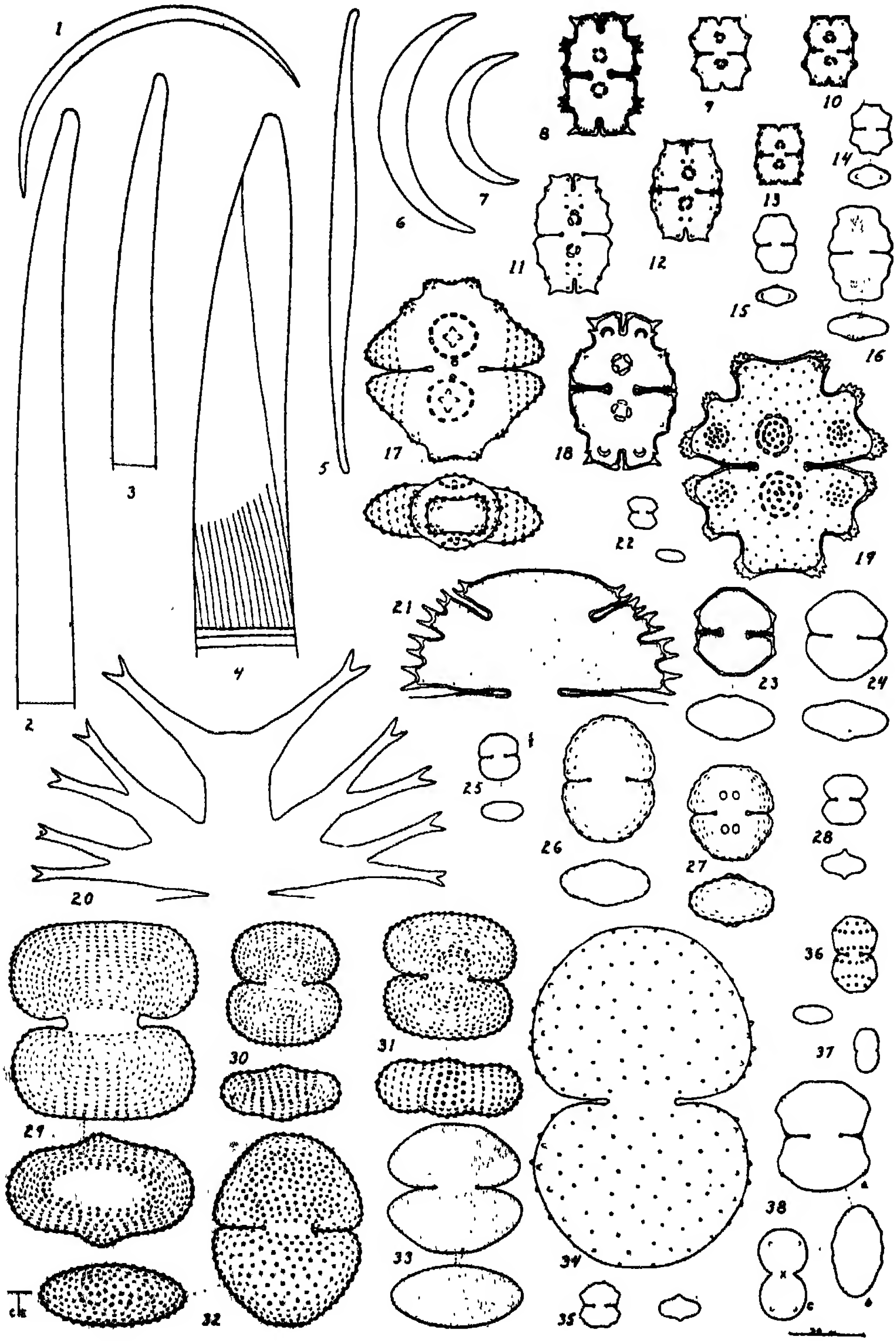
EXPLANATION OF PLATE II

Fig. 1. *Closterium parvulum* var. *angustum*. Fig. 2. *Closterium praelongum*. Fig. 3. *Closterium praelongum* var. *brevius?* Fig. 4. *Closterium pritchardianum*. Fig. 5. *Closterium subulatum*. Fig. 6. *Closterium venus*. Fig. 7. *Closterium venus* var. *incurvum*. Fig. 8. *Euastrum abruptum*. Fig. 9. *Euastrum abruptum* var. *lagöense*. Fig. 10. *Euastrum abruptum* var. *lagöense forma?* Figs. 11, 12. *Euastrum bidentatum*. Two cells with variable granulation. Fig. 13. *Euastrum dubium forma?* Fig. 14. *Euastrum binale* var. *hains*. Fig. 15. *Euastrum insulare* var. *silesiacum?* Fig. 16. *Euastrum luthemulleri*. Fig. 17. *Euastrum ohioense*, n. sp. Fig. 18. *Euastrum quebecense*. Fig. 19. *Euastrum verrucosum* var. *alatum*. Fig. 20. *Micrasterias radiata*. Fig. 21. *Micrasterias truncata*. Near the var. *semiradata*. Fig. 22. *Cosmarium abbreviatum*. Fig. 23. *Cosmarium angulare*. Fig. 24. *Cosmarium angulare* var. *canadense*. Fig. 25. *Cosmarium angulosum*. Fig. 26. *Cosmarium aphanichondrum*. Fig. 27. *Cosmarium bipunctatum*. Fig. 28. *Cosmarium bireme*. Fig. 29. *Cosmarium biretum*. Fig. 30. *Cosmarium biretum* var. *minus*. Fig. 31. *Cosmarium biretum* var. *trigibberum*. Fig. 32. *Cosmarium botrytis*. Fig. 33. *Cosmarium depressum* var. *achondrum*. Fig. 34. *Cosmarium dentatum*. Fig. 35. *Cosmarium crenulatum* var. *tumidulum*. Fig. 36. *Cosmarium difficile* var. *sublaeve*. Fig. 37. *Cosmarium exiguum?* Fig. 38a, b, c. *Cosmarium eriense*, n. sp. 38a, face view of cell; 38b, end view; 38c, side view.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of variable depth; vertical view elliptic with variously disposed protuberances on either side. One irregularity lobed and ridged chloroplast with one or more pyrenoids in each semicell.

1. ***Euastrum abruptum*** Nordst. (Pl. II, Fig. 8). L. 38–41μ, w. 27–28μ, w. polar lobe 18μ, isth. 6–7μ. East Harbor.

   There was some variability in the number and position of the granules, but in general the cells were remarkably constant.

2. ***Euastrum abruptum*** var. ***lagöense*** (Nordst.) Krieger (Pl. II, Fig. 9). L. 23–27μ, w. 18–21μ, w. polar lobe 12–14μ, isth. 4–5μ. East Harbor.

   The conical tooth on the lateral lobes of some cells was pronounced while in others it was lacking

3. ***Euastrum abruptum*** var. ***lagöense*** (Nordst.) Krieger forma? (Pl. II, Fig. 10). L. 24μ, w. 18μ, isth. 4μ. East Harbor.

   Several cells were seen which were constant in size, and were undoubtedly variations of the variety ***lagöense***. They differed by having three small granules on the margins of each lateral lobe and four pronounced granules within the apex on each side of the apical incision.

4. ***Euastrum bidentatum*** Naeg. (Pl. II, Figs. 11, 12). L. 32–41μ, w. 24–26μ, isth. 4–7μ. East Harbor, Pelee.

   The material, as might be expected, was quite variable. Although the general outline of the cells was fairly constant, there was a great deal of variation in the granulation, and sometimes in the granulation of the two semicells of one plant.

5. ***Euastrum dubium*** Naeg. forma? (Pl. II, Fig. 13). L. 19–23μ, w. 16–19μ, w. polar lobe 12–13μ, isth. 3–5μ. Haunk, East Harbor.

   The writer doubtfully includes this as a form of ***Eu. dubium*** Naeg. As only occasional cells were encountered, the extent of its variability has not been ascertained.

6. ***Euastrum binale*** (Turp.) Ehren. var. ***hians*** (W. West) Krieger (Pl. II, Fig. 14). L. 14–17μ, w. 11–13μ, isth. 3–4μ. Kelleys Isl.

7. ***Euastrum insulare*** (Wittr.) Roy var. ***silesiacum?*** Grönblad (Pl. II, Fig. 15). L. 19–20μ, w. 14μ, isth. 3–4μ. Pelee.

   There appears to be some question in the minds of various workers as to the exact differences between ***Eu. binale*** and its varieties and ***Eu. insulare*** and its varieties. This material has some characters referable to both, but it has been questionably placed with the latter.

8. ***Euastrum lütkemulleri*** Duc. (Pl. II, Fig. 16). L. 28μ, w. 21μ, isth. 7μ. Kelleys Isl.

   In outline this is almost identical to the figure given by Rich (1935) for ***Eu. insulare*** (Wittr.) Roy *forma*. The dimensions however are noticeably greater. Krieger (1937) includes this form in ***Eu. lütkemulleri*** Duc. In a very general way it may resemble this species in size and outline, but the wall characters seem to be entirely different. While Rich gives no clue as to the wall character or the shape of the vertical view beyond saying that it belongs to ***Eu. insulare***, the Lake Erie material definitely does not have the wall structure of ***Eu. lutkemulleri***. The writer believes that the Lake Erie and South African material is comparable and that it should be given specific rank. Until additional material is available for study, it will be referred to ***Eu. lütkmulleri*** Duc.

9. **Euastrum ohioense** Taft n. sp. (Pl. II, Fig. 17). Cells of medium size, as broad as long, dimensions extremely constant, deeply constricted, sinus closed; then opening outwards; semicells broadly pyramidate; polar lobe with a broad cuneate depression, each angle furnished with small, conical teeth, about four showing on the face within each angle; lateral margins slightly concave, each with a slight protuberance immediately below the polar lobe, each protuberance showing three conical teeth along the margin and three within the margin; basal lobes sharply rounded, each with about five vertical rows of conical granules; the center of each semicell furnished with four conical granules surrounded by a ring of flattened, rectangular granules and one conspicuous granule immediately above the isthmus; vertical view with a median tumid area showing three conical granules and a portion of the ring of granules, ends with about five rows of conical granules. L. 60μ, w. 60μ, w. polar lobe 23μ, isth. 16μ. East Harbor.

Cellulae mediocres, tam latae quam longae, mensuris constantissimis, alte constrictae, sinu clauso, deinde extra se pandente; semicellulae late pyramidatae; lobulo polare late et cuneate depresso, omni angulo dentibus parvis conicisque ornatis, circa quattuor in superficie in omni angulo aspectabilibus; margines laterales aliquantum concavi, quoque proxime infra lobulum polarem protuberationem parvem praebente, omni protuberatione tres dentes conicos secundum marginem et tres in margine praebente; lobuli basales acute rotundi, quoque circa quinque ordines rectos granulorum conicicorum praebente; centro omnis semicellulae quattuor granulis conicis orbe granulorum complanatorum orthogoniorumque et uno granulo conspicuo proxime super isthmum circumclusis ornato; a vertice aspectus, area tumida media tria granula conica et partem orbis granulorum praebente, in circa quinque ordines granulorum conicorum desinit. Long. 60μ, lat. 60μ, lat. isth. 16μ.

This desmid, with slight variations, has appeared in the writer's collections from Oklahoma and from fossil material in Ohio as well as from the Lake Erie Region. While the cell outline is constant the granulation appears to be somewhat variable in the specimens from the different localities. It should be compared with *Eu. hypochondrum* Nordst. from which it differs by having a depressed polar lobe, more sharply rounded basal angles, slightly different granulation of the polar lobe, and different dimensions.

10. *Euastrum quebecense* Irenee-Marie (Pl. II, Fig. 18). L. 55μ, w. 37μ, w. polar lobe 23μ, isth. 6μ. Pelee.
11. *Euastrum verrucosum* Ehren. var. *alatum* Wolle (Pl. II, Fig. 19). L. 76–80μ, w. 62–67μ, w polar lobe 30–35μ, isth. 16–18μ. Kelleys Isl., Pelee.

Micrasterias Ag. 1827

Cells variable in size, greatly compressed, with a very deep, nearly linear, median incision; semicells usually five lobed; apical lobe widely cuneate; lateral lobes bilobulate; face of semicell without granulate protuberances; one lobed chloroplast with many pyrenoids in each semicell

1. *Micrasterias radiata* Hass. (Pl. II, Fig. 20). L. 140μ, w. 106μ, w of polar lobe 89μ, isth 18μ. East Harbor.
2 *Micrasterias truncata* (Corda) Bréb. near the var., *semiradiata* Cleve (Pl. II, Fig. 21). L. 80–88μ, w. including teeth 92–96μ, w. without teeth 83μ, isth. 11–13μ. East Harbor

Members of the genus *Micrasterias* are rare in the Island Region of Lake Erie As yet there are no verified records of the occurrence of a single species on the Islands. The two species reported are from the mainland, and one of these two, *M. truncata* var ? is the only one that may be reported as abundant.

Cosmarium Corda 1834

Cells extremely variable in size, usually somewhat longer than broad, more or less compressed, usually with a fairly deep median constriction; cells variable in outline, without radiating processes or spines; vertical view usually oblong or elliptic, often with a central protuberance; chloroplasts usually axial, with one or two pyrenoids; cell wall varying from smooth to papillate, markings usually forming a definite pattern.

1. *Cosmarium abbreviatum* Racib. (Pl. II, Fig. 22). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 10–11μ, w. 9–10μ, isth. 2–3μ. Squaw Harbor.

The dimensions of these individuals were intermediate between *Cos. abbreviatum* Racib. and the forma *minor* W. & G. S. West. They have been referred to the species with the feeling that forma *minor* represents the minimum size range of the species.

2. *Cosmarium angulare* Johnson (Pl. II, Fig. 23). Cell wall indistinctly punctulate; chloroplasts axial, with one pyrenoid. L. 28–30μ, w. 25-27μ, isth. 6–8μ. Kelleys Isl., Fisher.
3. *Cosmarium angulare* var. *canadense* Irenee-Marie (Pl. II, Fig. 24). Cell wall indistinctly punctulate; chloroplasts axial, with one pyrenoid. L. 28–29μ, w. 26–27μ, isth. 7–8μ. Fisher, Wehrle, Pelee.

Irenee-Marie (1938) states in his description that this variety is distinguished from the species "*par l'absence de protubérance au milieu des hémisomates*, de sorte que la vue apicale est parfaitment elliptique." In the Lake Erie material which was associated

with the species, the vertical view showed a slight tumid condition. In other respects it resembles the specimens described by Irenee-Marie.

4. *Cosmarium angulosum* Bréb. (Pl. II, Fig. 25). Cell wall smooth, chloroplasts axial, with one pyrenoid. L. 16μ, w. 14μ, isth. 3–4μ. Squaw Harbor.
5. *Cosmarium aphanichondrum* Nordst. (Pl. II, Fig. 26). Chloroplasts axial, with one pyrenoid. L. 39–40μ, w. 32μ, isth. 9μ. Squaw Harbor, Beach pools, Middle Bass.
6. *Cosmarium bipunctatum* Borg. (Pl. II, Fig. 27). Chloroplasts axial, with one pyrenoid. L. 27–31μ, w. 25–30μ, isth. 8μ. Squaw Harbor.
7. *Cosmarium bireme* Nordst. (Pl. II, Fig. 28). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 16–17μ, w. 14–15μ, isth. 3–4μ. Squaw Harbor, East Harbor.
8. *Cosmarium biretum* Bréb. (Pl. II, Fig. 29). Chloroplasts axial, with two pyrenoids. L. 64–65μ, w. 60–64μ, isth. 21–23μ. Smith, Dock on North Bass.

   Nearly all the specimens exhibited the open sinus, a peculiar character for this species.
9. *Cosmarium biretum* var. *minus* Hansg. (Pl. II, Fig. 30). L. 39–41μ, w. 36–38μ, isth. 11–12μ. Middle Isle.

   The upper angles are rounded more than usual in this variety.
10. *Cosmarium biretum* var. *trigibberum* Nordst. (Pl. II, Fig. 31). L. 43μ, w. 43μ, isth. 14μ. Haunk, Squaw Harbor, Middle Bass.
11. *Cosmarium botrytis* Menegh. (Pl. II, Fig. 32). Chloroplasts axial with two pyrenoids. L. 60–66μ, w. 50–53μ, isth. 16–18μ. Pelee.

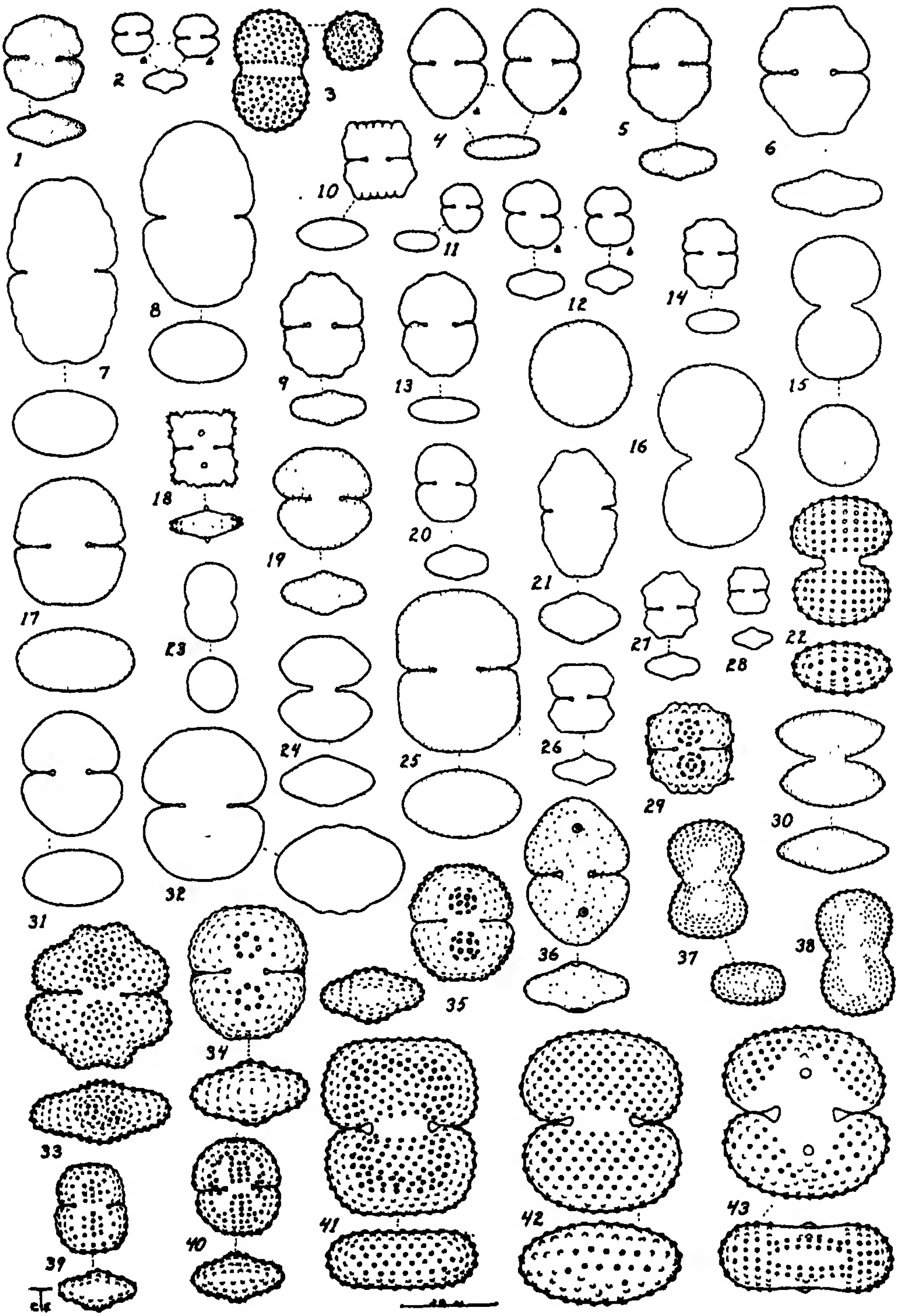
    This species was reported as being widely distributed in the Island Region by Pieters (1901) and Snow (1902). This has not been the case in the present survey where the writer has collected it only on Pelee Island.
12. *Cosmarium crenulatum* var. *tumidulum* Insam & Krieger (Pl. II, Fig. 35). Chloroplasts axial, with one pyrenoid. L. 15μ, w. 13μ, isth. 3–4μ. Exact locality unknown.

    Insam & Krieger (1936) give the dimensions of their specimens as 20.5 x 15.6 x 4.3μ. These are slightly larger than the dimensions of the present material. It should be compared to *Cos. perpusillum* West from which it differs by having more rounded apices instead of being retuse-truncate, and by its tumid vertical view.
13. *Cosmarium dentatum* Wolle (Pl. II, Fig. 34). Chloroplasts numerous, parietal, each with numerous pyrenoids. L. 115–142μ, w. 74–87μ, isth. 25–28μ. East Harbor.

    This is an extremely large species and exhibits more or less variation, especially in the number and prominance of the marginal teeth.
14. *Cosmarium depressum* (Naeg.) Lund. var. *achondrum* (Boldt) W. & G. S. West (Pl. II, Fig. 33). Cell wall finely punctulate; chloroplasts axial, with one pyrenoid. L. 33–43μ, w. 43–46μ, isth. 10–11μ. Wehrle.

EXPLANATION OF PLATE III

Fig. 1. *Cosmarium fontigenum*. Fig. 2. *Cosmarium geometricum* var. *suecicum*. 2a and 2b show slight variations in cell shape. Fig. 3. *Cosmarium globosum* var. *subaltum*. Fig. 4. *Cosmarium granatum*. 4a and 4b show slight variations in cell shape. Fig. 5. *Cosmarium granatum* var. *subgranatum*. Fig. 6. *Cosmarium hammeri* var. *protuberans*. Fig. 7. *Cosmarium holmiense*. Fig. 8. *Cosmarium holmiense forma?* Fig. 9. *Cosmarium impressulum* var. *suborthogona*. n. comb. Fig. 10. *Cosmarium humile* var. *striatum*. Fig. 11. *Cosmarium laeve*. Fig. 12. *Cosmarium laeve* var. *distentum forma?* 12a and 12b showing variations in size and shape. Fig. 13. *Cosmarium laeve* var. *octangulare*. Fig. 14. *Cosmarium meneghinii*. Fig. 15. *Cosmarium moniliforme* var. *punctata*. Fig. 16. *Cosmarium moniliforme* var. *subpyriforme*. Fig. 17. *Cosmarium nitidulum* var. *pseudovalidum* n. var. Fig. 18. *Cosmarium nobile*. Fig. 19. *Cosmarium phaseolus* var. *elevatum*. Fig. 20. *Cosmarium phaseolus forma minor?* Fig. 21. *Cosmarium pokornyanum*. Fig. 22. *Cosmarium portianum*. Fig. 23. *Cosmarium pseudarctoum*. Fig. 24. *Cosmarium pseudoprotuberans*. Fig. 25. *Cosmarium rectangulare*. Figs. 26, 27. *Cosmarium regnelli*. The two figures show extreme variations which may occur. Fig. 28. *Cosmarium regnelli* var. *minimum*. Fig. 29. *Cosmarium seelyanum*. Fig. 30. *Cosmarium subraciborskii* n. sp. Fig. 31. *Cosmarium subtumidum* var. *klebsii*. Fig. 32. *Cosmarium sulcatum* var. *sumatranum*. Fig. 33. *Cosmarium protractum*. Fig. 34. *Cosmarium punctulatum* var. *subpunctulatum*. Fig. 35. *Cosmarium subcostatum?* Fig. 36. *Cosmarium variolatum* var. *cataractarum*. Figs. 37, 38. *Cosmarium viride* var. *compressum* n. var. Two cells which vary in shape are figured. Fig. 39. *Cosmarium subcrenatum*. Fig. 40. *Cosmarium subcrenatum forma?* Fig. 41. *Cosmarium quadrum* var. *minus*. Fig. 42. *Cosmarium reniforme*. Fig. 43. *Cosmarium reniforme* var. *seminudum* var. nov.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15. *Cosmarium difficile* (Lutk.) var. *sublaeve* Schroeder (Pl. II, Fig. 36). Chloroplasts axial, with one pyrenoid. L. 21–26μ, w. 12–14μ, isth. 2–3μ. Kelleys Isl.

The Lake Erie material compares favorably with the figure of the variety given by Skuja (1928). Although he does not give the exact dimensions of the cells it would appear from the magnification that they are nearly the same. Dimensions of Michigan material reported by Prescott and Magnotta (1935) are somewhat greater.

16. **Cosmarium eriense** Taft n. sp. (Pl. II, Fig. 38). Cells of medium size, slightly longer than broad, deeply constricted, sinus linear, closed; semicells somewhat rectangular, each with a broad truncate lobe just below the apical angles, each lobe with a conical granule within the margin of the upper angle, apex truncate, upper lateral margins slightly retuse, basal angles broadly rounded, each furnished with a single medianly placed granule; vertical view ellipsoid with broadly rounded ends, each side with three undulations, four granules visible, one on either side near the ends. Cell wall indistinctly punctate. Chloroplasts single, axial, with one pyrenoid. L. 35–37μ, w. 30–33μ, isth. 11μ. Pelee.

Cellulae mediocres, paulo longiores quam latae, alte constrictae, sinu lineare clausoque; semicellulae eliquantum orthogoniae, quoque lobulum latum truncatum proxime infra angulos apicales praebente, omni lobulo granulum conicum in margine anguli superioris praebente, apex truncatus, margines laterales superiores aliquantum retusi, anguli basales late rotundati, quoque uno granulo, in medio locato, ornato; a vertice visae ellipticae, extremis late rotundatus, omni latere 3-undulato, quattiorgranuli aspectabiles, unus in utroque latere ad extrema. Nurus cellulae obscure punctatus. Chlorophyllaceae singulae, axiales, unum pyrenoidum praebentes. Long. 35–37μ, lat. 30–33μ, lat. isth. 11μ.

17. *Cosmarium exiguum* ? Arch. (Pl. II, Fig. 37). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 14–15μ, w. 7–8μ, isth. 6–7μ. Kelleys Isl.

18. *Cosmarium favum* West (Pl. IV, Fig. 1). Chloroplasts axial, with one pyrenoid. L. 62μ, w. 51μ, isth. 15μ. Kelleys Isl.

The lines delimiting the hexagonal areas are extremely delicate and may only be seen after critical lighting and focusing.

19. *Cosmarium fontigenum* Nordst. (Pl. III, Fig. 1). Cell wall finely punctulate; chloroplasts axial, with one pyrenoid. L. 22μ, w. 20–21μ, isth. 5–6μ. East Harbor.

It is almost a certainty that the writer passed over this small species in some of the earlier collections. Because of the curvature of the cells, the peculiar undulate character of the lateral margins is not readily evident when examining specimens, although the undulations are quite apparent in camera lucida figures.

20. *Cosmarium formulosum* Hof. (Pl. IV, Fig. 2). Chloroplasts axial, with two pyrenoids. L. 35–50μ, w. 32–42μ, isth. 9–13μ. Wehrle, Squaw Harbor.

21. *Cosmarium formulosum* forma? (Pl. IV, Fig. 3). L. 48–55μ, w. 44–48μ, isth. 11–13μ. Middle Isl.

Although the dimensions of this form intergrade with those of the species, the majority of the specimens are definitely larger. Otherwise the cells are similar.

22. **Cosmarium franzstonii** Taft n. sp. (Pl. IV, Fig. 4). Cells large, about one-fifth longer than broad, deeply constricted, sinus linear, closed; semicells ovate-pyramidate, apex slightly flattened, apical angles rounded; cell wall granulate with punctulations between the granules, granules near the apex large, becoming smaller and more numerous across the center and near the base of the semicell, center of semicell with two large protuberances which are evident because of their granulation; vertical view broadly elliptical with two large protuberances on either side, granules extending down to the protuberances larger than those in the center or at either end. Two massive chloroplasts in each semicell, each with one pyrenoid. L. 60–65μ, w. 50–55μ, isth. 16–20μ, thick 32μ. Gibraltar, Squaw Harbor, Middle Bass, Haunk, Kelleys Isl.

Cellulae magnae circa one-fifth longiores quam latae, late constrictae, sinu lineare clausoque; semicellulae ovato-pyramidatae, apex aliquantum complanatus, anguli apicales rotundati; murus cellulae granulatus, punctulationes inter granula habens, granula ad apicem magna, paullatim minores frequentioresque trans centrum et ad basam semicellulae. In centro semicellulae duae protuberationes magnae evidentes propter granu-

lationem; a vertice visae late ellipticae, duae protuberationes magnae in utroque aspectabiles, granulis in protuberationes maiores quam eae in centro aut in utroque extreme desuper patentibus. Duae chlorophyllaceae magnissimae in utraque semicellula, quaque unum pyrenoidum habente. Long. 60–65μ, lat. 50–55μ, lat. isth 16–20μ.

The form of the semicells, the granulation, and the widely separated central protuberances separate it from *Cos. turpinii* and *Cos. didymoprotupsum*.

23. ***Cosmarium geometricum*** W. & G. S. West var. ***suecicum*** Borge (Pl. III, Fig. 2). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 12μ, w. 11μ, isth. 3μ. Kelleys Isl.

24. ***Cosmarium globosum*** Bulh. var. ***subaltum*** Messikommer (Pl. III, Fig. 3). Cell wall finely granulate; chloroplasts axial, with one pyrenoid. L. 35μ, w. 20μ, isth. 16μ Kelleys Isl.

This form was rarely found in the collections. It should be compared to *Cos. globosum* var. ***granulatum*** Schmidle and also with *Cos. trachypolum* West var. *aequaliter-granulata* Lutk. which has punctae between the granules.

25. ***Cosmarium granatum*** Bréb. (Pl. III, Fig. 4). Cell wall finely granulate; chloroplasts axial, with one pyrenoid. L. 23–27μ, w. 18–19μ, isth. 4–5μ. Haunk, Fisher, Smith, Squaw Harbor, Kelleys Isl., Pelee.

This highly variable species is widely distributed over the region. The lateral margins vary from strongly convex to strongly retuse, the latter condition being exemplified best by the individuals from Squaw Harbor. These might well be placed in the variety ***concavum*** Lagerh. which is considered as a local variation by some workers.

26. ***Cosmarium granatum*** var. ***subgranatum*** Nordst. (Pl. III, Fig. 5). Cell wall finely granulate, chloroplasts axial, with one pyrenoid. L. 25–29μ, w. 18–21u, isth. 4–5μ. Haunk, Fisher, Wehrle, Pelee.

27. ***Cosmarium hammeri*** Reinsch var. ***protuberans*** W. & G. S. West (Pl. III, Fig. 6). Cell wall finely punctate; chloroplasts axial, with one pyrenoid. L. 32–35μ, w. 25–29μ, isth. 8–10μ. Pelee.

28. ***Cosmarium holmiense*** Lund. (Pl. III, Fig. 7). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 50μ, w. 30μ, isth. 16μ. Kelleys Isl.

29. ***Cosmarium holmiense*** Lund. forma? (Pl. III, Fig. 8). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 48–50μ, w. 28–30μ, isth. 16μ. Kelleys Isl.

The dimensions and cell outline are almost exactly those of *Cos. holmiense* var. ***trigonum*** Nordst. The vertical view, however, is oval instead of triangular.

30. ***Cosmarium impressulum*** var. **suborthogona** (W. & G. S. West) Taft, new comb. (Pl. III, Fig. 9).

(***Cosmarium suborthogona*** Racib., Desm. Nowe, 1889, p. 85, t. 5, fig. 29.)

(***Cosmarium impressulum*** forma ***suborthogona*** W. & G. S. West, British Desmidiaceae, 1908, Vol. 3, p. 88.)

Cells rather small, nearly 1½ times as long as broad, constriction deep, closed, with a dilated apex; semicells subsemicircular, margin regularly eight-undulate, including basal angles, undulations equal, two at the apex and two on each side; vertical view elliptic, with a slight protuberance on each side near the middle; cell wall very finely punctulate; chloroplasts axial, with one pyrenoid. L. 25–27μ, w. 19–21μ, isth. 4–6μ. Haunk.

This desmid was first described by Raciborski as *Cos. suborthogona* and differed from *Cos. impressulum* only in the presence of the protuberances in vertical view. The Wests (1908) considered this to be an insufficient specific character, so placed it as *forma suborthogona* of *Cos. impressulum*. As the character appears to be constant, and as individuals have now appeared in widely separated areas, the writer gives it varietal rank.

31. ***Cosmarium humile*** (Gay) Nordst. var. ***striatum*** (Boldt) Schmidle (Pl. III, Fig. 10). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 16–19μ, w. 16–19μ, isth. 4μ. Wehrle, Haunk, Fisher, Smith, Squaw Harbor.

32. ***Cosmarium kjellmani*** Wille var. ***grande*** Wille (Pl. IV, Fig. 5). Chloroplasts axial, with two pyrenoids. L. 46–50μ, w. 37–39μ, isth. 11–13μ. Squaw Harbor, Dock at N. Bass.

33. ***Cosmarium laeve*** Raben. (Pl. III, Fig. 11). Cell wall appearing smooth, usually sparsely punctate, colorless; chloroplasts axial, with one pyrenoid. L. 13–14μ, w. 11–12μ, isth. 2–3μ. Squaw Harbor, East Harbor.

34. *Cosmarium laeve* var. *distentum* G. S. West forma? (Pl. III, Fig. 12). Chloroplasts axial, with one pyrenoid. L. 14–18μ, w. 11–15μ, isth. 3–4μ. Kelleys Isl., Beach pools on Middle Bass.

The cell outline is distinctly that of *Cos. laeve* but the vertical view is tumid. The specimens were somewhat smaller than those described by West, otherwise they were similar.

35. *Cosmarium laeve* var. *octangulare* (Wille) W. & G. S. West (Pl. III, Fig. 13). L. 26μ, w. 18μ, isth. 7μ. Pelee.

36. *Cosmarium lundellii* Delp. var. *ellipticum* West (Pl. IV, Fig. 6). Cell wall with small sparse granules; chloroplasts axial, ridged, with two pyrenoids. L. 69–87μ, w. 50–57μ, isth. 14–16μ. Fisher.

Although smaller, these cells slightly resemble *Cos. ochthodes* var. *aequalis* Insam & Krieger.

37. *Cosmarium margaritatum* (Lund.) Roy & Biss. (Pl. IV, Fig. 7). Chloroplasts axial, with two pyrenoids. L. 57–60μ, w. 46–48μ, isth. 18μ. Wehrle.

38. *Cosmarium meneghinii* Bréb. (Pl. III, Fig. 14). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 17–18μ, w. 11–14μ, isth. 3.5μ. Squaw Harbor, Beach pools on Middle Bass.

39. *Cosmarium moniliforme* (Turp.) Ralfs var. *punctata* Lagerh. (Pl. III, Fig. 15). Cell wall finely punctulate; chloroplasts axial, with about 6–7 radiating plates, one pyrenoid L. 37–41μ, w. 23μ, isth. 7μ. East Harbor.

40. *Cosmarium moniliforme* var. *subpyriforme* W. & G S. West (Pl. III, Fig. 16). Cell wall finely punctulate; chloroplasts with 10–11 flanges, one pyrenoid. L. 44–48μ, w. 25–28μ, isth. 11–12μ. Pelee.

In the original description of this variety only one set of dimensions is given. Unless the Wests' material was extremely constant, they saw only one specimen. While the dimensions of the Lake Erie material are distinctly greater, the writer feels that they possibly exhibit the upper limits of the size range. Material from Arkansas, collected by Couch (unpublished) is decidedly smaller, the dimensions being 35 x 20 x 6μ

41. *Cosmarium nitidulum* De Not. var. **pseudovalidum** Taft n. var. (Pl. III, Fig. 17). Cells slightly longer than broad, deeply constricted, sinus linear; semicells subrectangular, basal angles nearly rectangular, more or less produced, upper angles broadly rounded, apex truncate-convex. Vertical view elliptic. Cell wall punctate. Chloroplasts axial, with one pyrenoid. L. 33–35μ, w. 28–30μ, isth. 6–7μ. Kelleys Isl.

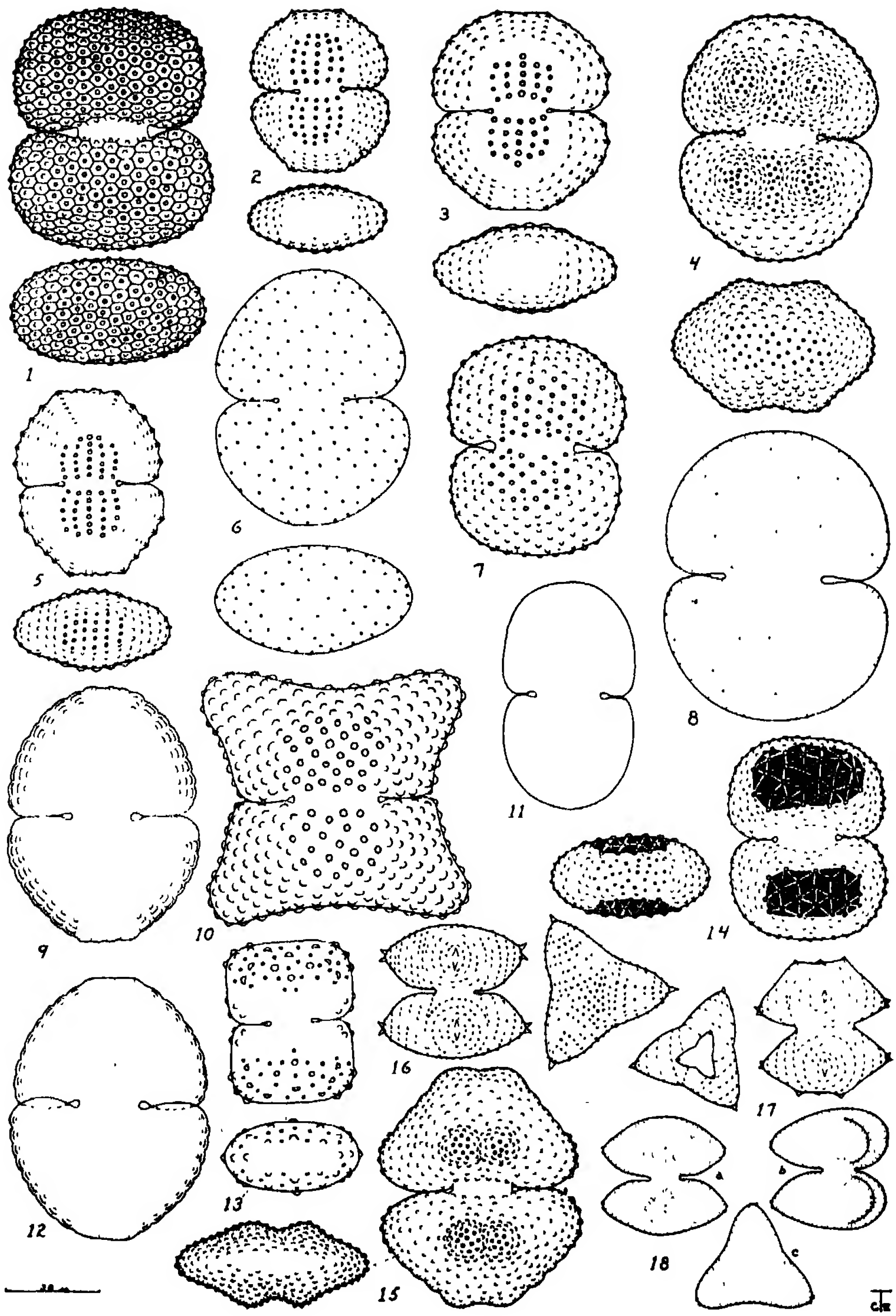
C. medio sinu lineare profundo constrictum; semicellulis transverse subrectangularis, diametro maximo paullo supramedio, angulis inferioribus obtusis rotundatis, angulis superioribus late rotundatis, apicibus truncatis vel convexis; cellulis a vertice ellipticis. Membrana distincte punctata. Pyrenoides singuli. Long. 33–35μ, lat. 28–30μ; lat. isth. 6–7μ.

This variety is separated from *Cos. nitidulum* because of the rectangular or produced basal angles. In this respect it resembles *Cos. pseudonitidulum* var. *validum*. It differs from this variety by its smaller dimensions and the presence of only one pyrenoid in each chloroplast, the latter being a distinctive character of *Cos. nitidulum*.

42. *Cosmarium nobile* (Turner) Krieger (Pl. III, Fig. 18). This species was incompletely described as a species of *Euastrum* by Turner (1892) from notes left by Dr. Wallich.

EXPLANATION OF PLATE IV

Fig. 1. *Cosmarium favum*. Fig. 2. *Cosmarium formulosum*. Fig. 3. *Cosmarium formulosum forma?* Fig. 4. *Cosmarium franzstonii* n. sp. Fig. 5. *Cosmarium kjellmani* var. *grande*. Fig. 6. *Cosmarium lundellii* var. *ellipticum*. Fig. 7. *Cosmarium margaritatum*. Fig. 8. *Cosmarium pachydermum* var. *aethiopicum*. Fig. 9. *Cosmarium ochtodes*. Fig. 10. *Cosmarium porrectum*. Fig. 11. *Cosmarium subcucumis*. Fig. 12. *Cosmarium subochthodes*. Fig. 13. *Cosmarium triplicatum*. Fig. 14. *Cosmarium subnudiceps* var. *granulatum* n. var. Fig. 15. *Cosmarium turpinii* var. *podolicum*. Fig. 16. *Staurastrum avicula* var. *subarcuatum*. Fig. 17. *Staurastrum biarcuus* n. sp. Fig. 18a, b, c. *Staurastrum bieneanum*. Figs. 18a and b are face views of the cell from different angles; 18c is the end view.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Krieger (1937) has referred it to the genus *Cosmarium*. In the original description Turner states, "A vertice et a latere non cl. Wallichio observatum" and "Judging from the drawing it appears to have one amylum-corpuscle (large) in each semicell."

The vertical view as figured by the writer, is elliptic with slight tumid areas on either side, each having a distinct conical granule. This granule is also evident in face view and may be the "One amylum-corpuscle" referred to in Turner's description, although it is much smaller than the structure shown in his figure. If his statement "one amylum-corpuscle" does refer to the pyrenoid, then there is some discrepancy as the present material shows two pyrenoids. L. 17–18μ, w. 17–18μ, isth. 4μ. Haunk.

43. *Cosmarium ochlodes* Nordst. (Pl. IV, Fig. 9). Cell wall punctate within the marginal crenations; chloroplasts axial, with two pyrenoids. L. 67–74μ, w. 50–55μ, isth. 14–16μ. Pelee, Kelleys Isl.

44. *Cosmarium pachydermum* Lund var. *aethiopicum* W & G. S. West (Pl. IV, Fig. 8). Cell wall punctate, punctae interspersed with very fine punctulations; chloroplasts axial, with two pyrenoids. L. 78–83μ, w. 62μ, isth. 27–30μ. Pelee.

45. *Cosmarium phaseolus* Bréb. var. *elevatum* Nordst. (Pl. III, Fig. 19). Cell wall smooth, colorless; chloroplasts axial, with one pyrenoid. L. 23–25μ, w. 21–23μ, isth. 4–5μ. East Harbor, Squaw Harbor, Haunk, Wehrle.

46. *Cosmarium phaseolus* forma *minor?* Boldt. (Pl. III, Fig. 20). Cell wall smooth, colorless; chloroplasts axial, with one pyrenoid. L. 17–20μ, w. 16μ, isth. 4μ. Fisher, Pelee.

The shape of the semicells of this form is almost exactly that of *Cos. phaseolus* var. *rectangulare* Insam & Krieger (1936) but the dimensions are about half those of this variety. In size and cell outline it is very near forma *minor* Boldt as figured by Skuja (1928) and Irenee-Marie (1938).

47. *Cosmarium pokornyanum* (Grun.) W. & G. S. West (Pl. III, Fig. 21). Cell wall sparsely punctate; chloroplasts axial, with one pyrenoid. L. 33–35μ, w. 18–19μ, isth. 10–11μ. Kelleys Isl.

This species should be compared with *Cos. laeve* var. *septentrionale* Wille from which it differs by having a rhomboid-ovoid vertical view and a shallow sinus.

48. *Cosmarium porrectum* Nordst. (Pl. IV, Fig. 10). Cell wall with minute pores between the granules; chloroplasts axial, each with one pyrenoid. L. max. 64–73μ, l. min. 57–62μ, w. max. 69–83μ, w. min. 51–57μ, isth. 21–23μ. East Harbor.

49. *Cosmarium portianum* Arch. (Pl. III, Fig. 22). Chloroplasts axial, with one pyrenoid. L. 33–37μ, w. 24–27μ, isth. 9–10μ. East Harbor.

50. *Cosmarium protractum* (Naeg.) De Bary (Pl III, Fig. 33). Chloroplasts axial, with two pyrenoids. L. 33–46μ, w. 30–37μ, isth. 9–10μ. Haunk, East Harbor.

51. *Cosmarium pseudarctoum* Nordst. (Pl. III, Fig. 23). Cell wall smooth, colorless; chloroplasts axial, with about 4–5 radiating plates and one pyrenoid. L. 19–20μ, w. 14μ, isth. 10–11μ. Kelleys Isl.

52. *Cosmarium pseudoprotuberans* Kirchn. (Pl. III, Fig. 24). Cell wall appearing smooth, but with very fine punctulations; chloroplasts axial, with one pyrenoid. L. 25–27μ, w. 23–24μ, isth. 5–6μ. East Harbor.

53. *Cosmarium punctulatum* Bréb. var. *subpunctulatum* (Nordst.) Borges (Pl. III, Fig. 34). Chloroplasts axial, with one pyrenoid. L. 32μ, w. 30μ, isth. 7μ. Kelleys Isl.

54. *Cosmarium quadrum* Lund. var. *minus* Nordst. (Pl. III, Fig. 41). Chloroplasts axial, with two pyrenoids. L. 44μ, w. 35μ, isth. 14μ. Haunk.

55. *Cosmarium rectangulare* Grun. (Pl. III, Fig. 25). Cell wall punctate; chloroplasts axial, with one pyrenoid. L. 42–44μ, w. 34–35μ, isth. 11–12μ. Pelee.

56. *Cosmarium regnelli* Wille (Pl. III, Figs. 26, 27). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 17–18μ, w. 14–17μ, isth. 4–5μ. Smith, Wehrle, Fisher.

Figure 26 is that of *Cos. regnelli* Wille, while Figure 27 illustrates one of the more extreme variations. In all cases the Lake Erie material possessed a tumid vertical view, a condition which has not been generally reported. However the figures of this species by Insam and Krieger (1936) show the vertical view as either elliptic or tumid. Since this character is used in distinguishing varieties of other species, future studies may result in the segregation of a variety on the basis of the tumid condition.

57. *Cosmarium regnelli* var. *minimum* Eichl. et Gutw. (Pl. III, Fig. 28). Cell wall smooth; chloroplasts axial, with one pyrenoid. L. 11–14μ, w. 11–12μ, isth. 3–4μ. Wehrle.

Specimens of this variety, as in the species, were tumid in vertical view. They resemble closely the figure given by Messikommer (1935).

58. *Cosmarium reniforme* (Ralfs) Arch. (Pl. III, Fig. 42). Chloroplasts axial, with two pyrenoids. L. 48μ, w. 44μ, isth. 14μ. Haunk.

59. *Cosmarium reniforme* var. **seminudum** Taft n. var. (Pl. III, Fig. 43). Semicells granulate only in upper part, granules extending in oblique series from near the basal angles to the middle of the apex, from which a granulate area extends downward nearly to the center of the semicell which is furnished with one large conical granule, cell otherwise not granulate; vertical view oblong-rectangular with broadly rounded ends, lateral margins slightly concave with one large granule on either side, ends with six or seven rows of granules, these granulate areas being connected by two separate series of two or three rows of granules across the end of the cell, median portion of vertical view without granules. L. 46–48μ, w. 41μ, isth. 14μ. Squaw Harbor.

Semicellulae granulatae solum in parte superiore, granuli in serie obliqua de loco propter angulos basales ad medium apicem, a quo area granulata prope ad centrum semicellulae, uno granulo magno conico praeditae, desuper patet, cellula aliter non granulata; a vertice visae oblongo-orthogoniae, extremis late rotundatis, margines laterales aliquantum concavi, unum granulum magnum in utroque latere haventes, in sex aut septem ordines granulorum desinit, his granulis duabus seriebus separatis duorum aut trium ordinum granulorum trans extremum cellulae inter se conjunctis, pars media a vertice visa sine granulis. Long. 46–48μ, lat 41μ, lat. isth 14μ

60. *Cosmarium seelyanum* Wolle (Pl. III, Fig. 29) Chloroplasts axial, with one pyrenoid. L. 23μ, w. 23μ, isth. 6–7μ. East Harbor.

The original figure and description of this species (Wolle, 1884) shows the upper angles of the semicells to be slightly more produced and the dimensions of the cells a little greater than in the Lake Erie material. Otherwise they are comparable.

61. *Cosmarium subcostatum?* Nordst. (Pl. III, Fig. 35). Chloroplasts axial, with one pyrenoid. L. 32μ, w. 27μ, isth. 7μ. Middle Isl.

The original figure of this species by Nordstedt (1876) shows a curved row of granules just below the granulate central protuberance. Later figures by other workers do not always show this row of granules. As the writer did not see enough of this material to determine the variations, it has been doubtfully assigned to this species

62. *Cosmarium subcrenatum* Hantzsch (Pl III, Fig. 39). Chloroplasts axial, with one pyrenoid. L. 23μ, w. 19μ, isth. 7μ. Kelleys Isl.

63. *Cosmarium subcrenatum* forma? (Pl. III, Fig. 40). Chloroplasts axial, with one pyrenoid. L. 21–25μ, w. 19–23μ, isth. 5–6μ. Squaw Harbor.

64. *Cosmarium subcucumis* Schmidle (Pl. IV, Fig 11). Cell wall smooth; chloroplasts axial, with two pyrenoids L. 55–60μ, w 35–37μ, isth 14–19μ Kelleys Isl., Pelee

65. *Cosmarium subnudiceps* West & West var **granulatum** Taft n. var. (Pl. IV, Fig. 14). Cell wall densely granulate, granules not arranged in series. L. 50–54μ, w. 41–43μ, isth. 10–11μ. Kelleys Isl., Pelee, East Harbor.

Membrana granulata, granulis non regulariter ordinatis. Long. 50–54μ, lat. 41–43μ, isth. 10–11μ.

This variety differs from the species by having the cell wall which borders the sculptured areas covered with small granules. The dimensions are also somewhat greater.

66. *Cosmarium subochthodes* Schmidle (Pl. IV, Fig. 12). Cell wall with small granules; chloroplasts two, axial, each with one pyrenoid. L. 64μ, w. 50μ, isth. 16μ. Haunk.

67. **Cosmarium subraciborskii** Taft n. sp. (Pl. III, Fig. 30). Cells slightly broader than long, deeply constricted, sinus open; semicells transversely elliptic to nearly fusiform, lateral angles sharply rounded; cell wall minutely granulate, granules arranged in 18–20 vertical series across each semicell; vertical view narrowly elliptic with a slight median protuberance on either side, ends sharply rounded; a single chloroplast with one pyrenoid in each semicell. L. 23–27μ, w. 25–30μ, isth. 5–7μ. Squaw Harbor, Kelleys Isl., East Harbor.

C. paullo latius quam longius, profundo sinu ampliato constrictum; semicellulis transversis ellipticis vel fere fusiformis, angulis lateribus acutis rotundatis; membrana granulis (Verrucis minutis) in 18–20 series perpendiculares ordinatis. Semicellulae a vertice aspectae ellipticae medio utrimque tumidae. Massa chlorophyllacea singulae, pyrenoidae singulae. Long. 23–27μ; lat. 25–30μ, lat. isth 5–7μ.

In general appearance this species stands near *Cos raciborskii*. However its dimensions are only slightly more than one-half those of Lagerheim's species. The granulation is in distinct vertical series while that of *Cos. raciborskii* is described as "series oblique desussatas regulariter." Differences are also apparent in vertical view in which the Lake Erie material exhibits slight but distinct median protuberances and sharply rounded ends.

68. *Cosmarium sulcatum* Nordst. var. *sumatranum* Schmidle (Pl. III, Fig. 32). Cell wall smooth; chloroplasts axial, with one pyrenoid L. 39μ, w. 29–32μ, isth. 9μ. Kelleys Isl.

The dimensions of the present material are somewhat greater than those given by Schmidle (1895). Otherwise the material is comparable.

69. *Cosmarium subtumidum* Nordst. var. *klebsii* (Gutw.) W. & G. S. West (Pl. III, Fig. 31) Cell wall smooth to very finely punctulate; chloroplasts axial, with one pyrenoid L. 32μ, w. 25–28μ, isth. 7–9μ. Squaw Harbor.

70. *Cosmarium triplicatum* Wolle (Pl. IV, Fig. 13). Chloroplasts axial, with two pyrenoids. L. 44–46μ, w. 36–37μ, isth. 11–12μ. East Harbor, Kelleys Isl.

The original figure of this species by Wolle (1884) left much to the imagination concerning the central granulation. It was not until West (1898) had examined and figured numerous specimens from various parts of the United States that the true nature of the cell wall was recognized.

71. *Cosmarium turpinii* Bréb. var. *podolicum* Gutw. (Pl. IV, Fig. 15). Chloroplasts axial, with two pyrenoids. L. 57–64μ, w. 50–53μ, isth. 12–14μ. Wehrle, Fox, Fisher, Pelee.

This variety is rather widely distributed in the Island Region. The specimens from Pelee Island had a flat granulate apex and very slight double tumers.

72. *Cosmarium variolatum* Lund. var. *cataractarum* Racib. (Pl. III, Fig. 36). Chloroplasts axial, with one pyrenoid. L. 37–43μ, w. 25–30μ, isth. 6–7μ. Fisher, Wehrle, Squaw Harbor, Gibraltar, Kelleys Isl.

The lateral margins of the semicells vary from convex to retuse, although usually straight or convex. It should be compared to *Cos. granatum* var. *oscellatum* G. S. West which is not tumid in vertical view.

73. *Cosmarium viride* (Corda) Josh. var. **compressum** Taft n. var. (Pl. III, Figs. 37, 38). Cells rather small, slightly constricted, sinus obtuse; semicells obovate-circular with slightly depressed apices. Vertical view compressed circular. Cell wall finely but distinctly granulate, granules arranged in concentric rows within the margins of the semicells. Chloroplasts axial, with one pyrenoid. L. 30–32μ, w. 18–22μ, isth. 12–14μ. Kelleys Isl.

Semicellulis depressis obovatis-circularis; a vertice aspectis compressis circularis. Membrana granulis minutis, in series concentricas dispositis praedita. Long. 30–32μ; lat 18–22μ; lat. isth. 12–14μ.

Because of an inadequate description, the identity of *Colopella viridis* Corda remains

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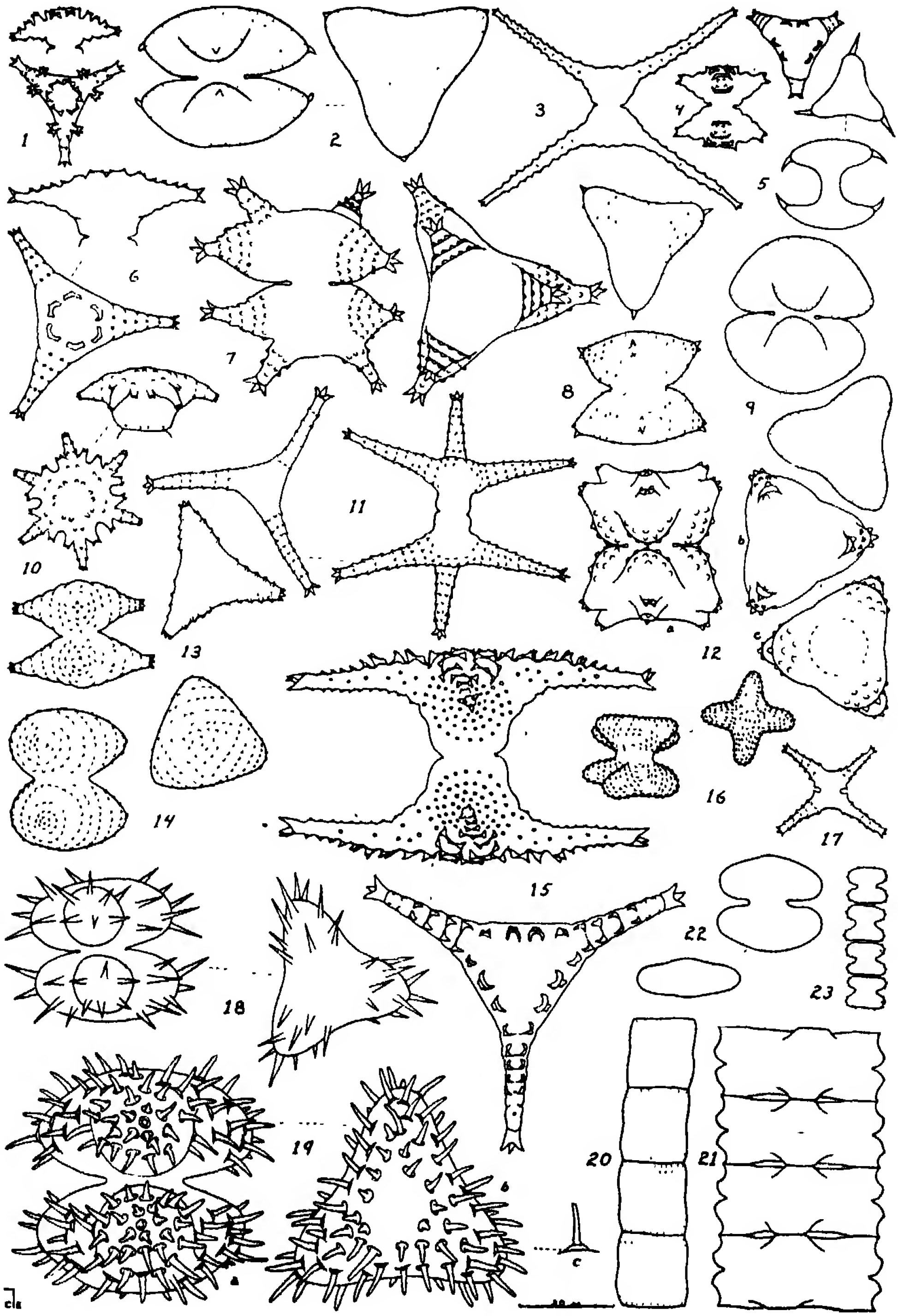
EXPLANATION OF PLATE V

Fig. 1. *Staurastrum bicoronatum* var. *tridentatum* n. var. Fig. 2. *Staurastrum brevispinum* var. *canadense* n var. Fig. 3. *Staurastrum chaetoceras*. Fig. 4. *Staurastrum crenulatum*. Fig. 5. *Staurastrum cuspidatum*. Fig. 6. *Staurastrum floriferum?* Fig. 7. *Staurastrum furcigerum*. Fig. 8. *Staurastrum granulosum*. Fig. 9. *Staurastrum orbiculare*. Fig. 10. *Staurastrum ornatum* var. *asperum*. Fig. 11. *Staurastrum paradoxum*. Fig. 12a, b, c. *Staurastrum peleii* n. sp. 12a, face view; 12b, upper surface of semicell; 12c, lower surface of semicell. Fig. 13. *Staurastrum polymorphum*. Fig. 14. *Staurastrum punctulatum* var. *kjellmanii*. Fig. 15. *Staurastrum sebaldi* var. *ornatum*. Fig. 16. *Staurastrum striolatum*. Fig. 17 *Staurastrum tetracerum*. Fig. 18. *Staurastrum setigerum*. Fig. 19a, b, c. *Staurastrum polytrichum* var. *ornatum*. n. var. Fig. 19a, face view; 19b, end view; 19c, detail of spine. Fig. 20. *Hyalotheca mucosa*. Fig. 21. *Desmidium swartzii*. Fig. 22. *Spondylosium luetkemulleri?* Fig. 23. *Sphaerozosma granulatum*.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somewhat questionable. Joshua (1885) discovered a plant from Pictou, Nova Scotia, which he referred to Corda's species and included it in the genus *Cosmarium*. His figure indicates that the wall was punctate. Turner, during the same year (1885), reported *Cosmarium cordanum* Bréb. from Nova Scotia. This was the same desmid as reported by Joshua as *Cos. viridis* (Corda) but in his description Turner states "Cell-coat lightly granular or punctate. End view circular." The West's in their British Desmidiaceae (1908) report the species and a forma *minor* West. Again the cell wall is described as punctate. The dimensions of West's forma *minor* are almost exactly those of the present material while in all recorded cases those of the species are distinctly greater. Also the vertical view of the species as well as of West's forma *minor* has been consistently reported as circular while the Ohio material is consistently compressed. Because of these differences the Lake Erie material has been given varietal rank.

Staurastrum Meyen 1829

Cells of variable size, usually as broad or broader than long, usually radially symmetrical, median constriction more or less deep; semicells variable in outline, with the angles frequently produced into elongate, hollow processes, 2–12 radiate in vertical view; cell wall smooth to granulate, or with variously arranged spines or verrucae; chloroplasts one per semicell, axial, with radiating lobes, and one pyrenoid.

1. *Staurastrum avicula* Bréb. var. *subarcuatum* (Wolle) W. West (Pl. IV, Fig. 16). L. 36–37μ, w. 38–40μ, isth. 9–10μ. Wehrle.
2. **Staurastrum biarcuus** Taft n. sp. (Pl. IV, Fig. 17). Semicells truncate- pyramidate, base convex, apex retuse, sides straight, sinus deep, rapidly opening outward; cell wall granulate, granules arranged in concentric series about the angles; each basal angle furnished with two vertically arranged teeth, the lower somewhat smaller than the one above; each apical angle furnished with a single, broad, conical granule. Vertical view triangular; each angle exhibiting a single tooth-like granule; sides straight or slightly convex, sharply retuse at the center. Within the vertical view formed by the basal angles, and an exact miniature, is the smaller vertical view of the apical angles. L. 35–36μ, w. 32–34μ, isth. 14μ. Kelleys Isl.

   Semicellulae truncato-pyrimidatae, basis convexa, apex retuses, lateres recti; sinus altus, rapide extra se pandens; murus cellulae granulatus, granulis in seriebus concentricis circum angulos dispositis; omnis angulus basalis duobus dentibus a vertice positis praeditus, inferiore paulo minore quam superiore; omnis angulus apicalis granulo singulo, lato, conicoque praeditus. A vertice visae triangulae; omnis angulus granulum singulum denti simile praebens; lateres recti aut aliquantum convexi, acute retusi ad centrum. In apsectu a vertice angulis basalicibus facto, et tabella minuta exacta, est aspectus minor a vertice angulorum apicalum. Long. 35–36μ, lat. 32–34μ, lat. isth. 14μ.

   This species should be compared to *St. paniculosum* Wolle which has two small teeth at the end of each basal angle. It differs from Wolle's species in its open instead of a closed sinus, the presence of granules on the upper angles, and the retuse sides in vertical view.
3. *Staurastrum bicoronatum* Johnson var. **tridentatum** Taft n. var. (Pl. V, Fig. 1). Apex of semicells distinctly elevated; each lateral process in vertical view with three short spines. L. 23μ, w. 38–43μ, isth. 4–6μ. East Harbor.

   Varietas type paullo major; semicellulis apicibus convexis; a vertice aspectae processibus lateralis cum tres spinis brevis. Long. 23μ; lat. 38–43μ; lat. isth. 4–6μ.

   This variety differs from the species by having three short instead of two long spines terminating each lateral process. The dimensions are also somewhat greater while the apex of the semicell is more convex. It differs from the variety described by West (1896) by having more ornamentations, and especially by the presence of the circularly arranged verrucae around the apex.
4. *Staurastrum bieneanum* Raben. (Pl. IV, Fig. 18). Cell wall finely granulate, two larger granules at each angle. L. 31–32μ, w. 30–34μ, isth. 7–8μ. Kelleys Isl.
5. *Staurastrum brevispinum* Bréb. var. **canadense** Taft n. var. (Pl. V, Fig. 2). This variety

differs from the species by having depressed-hexagonal semicells with rather acute lateral angles. Cell wall obscurely granulate. L. 46–48μ, w. 44μ, isth. 9–10μ. Pelee.

Haec varietas differt a typo semicellulis depresso-hexagonis, angulis lateralibus acutis. Membrana granulata obscure. Long. 46–48μ; lat. 44μ; lat. isth. 9–10μ.

6. *Staurastrum chaetoceras* (Schroeder) G. M. Smith (Pl. V, Fig. 3). L. plus processes 40–75μ, l. minus processes 18–25μ, w. plus processes 60–73μ, w. minus processes 14–16μ, isth. 4–7μ. Hatchery Bay.
7. *Staurastrum crenulatum* Delp. forma? (Pl. V, Fig. 4). L. 21μ, w. 23μ, isth. 5μ. Wehrle.
8. *Staurastrum cuspidatum* Bréb. (Pl. V, Fig. 5). L. 18–20μ, w. minus spines 16–18μ, isth. 4–5μ. Smith.
9. *Staurastrum floriferum* ? W. & G. S. West (Pl. V, Fig. 6). L. 34–46μ, w. plus processes 48–50μ, isth. 7–9μ. Wehrle, Smith, Haunk.

   The original figure of this species by West (1895) illustrates a specimen which was much less robust than any seen by the writer. The sculpturing of the wall, however, is nearly identical.
10. *Staurastrum furcigerum* Bréb. (Pl. V, Fig. 7). L. minus processes 41μ, w. plus processes 55–57μ, isth. 13u. Pelee.
11. *Staurastrum granulosum* (Ehren.) Ralfs (Pl. V, Fig. 8). L. 27–32μ, w. 25–32μ, isth. 10–14μ. Kelleys Isl.
12. *Staurastrum orbiculare* Ralfs var.? (Pl. V, Fig. 9). L. 42μ, w. 40μ, isth. 11μ. Pelee.
13. *Staurastrum ornatum* Turner var. *asperum* (Perty) Schmidle (Pl. V, Fig. 10). L. 26–28μ, w. 37μ, isth. 8–10μ. Pelee, East Harbor.
14. *Staurastrum paradoxum* Meyen (Pl. V, Fig. 11). L. minus processes 28–29μ, w. plus processes 53u, w. minus processes 12–15μ, isth. 7μ. Hatchery Bay.
15. **Staurastrum peleii** Taft n. sp. (Pl. V, Fig. 12). Cells of medium size, square or slightly rectangular in face view; sinus deep and closed; semicells horizontally rectangular, with three apical angles continued into two short, truncate, vertically arranged processes, basal angles broadly rounded and furnished with three concentric rows of granules, three granules of which show along each margin; vertical view of semicell triangular, each angle which represents the basal angle of the semicell broadly rounded, superimposed and projecting beyond this angle is the lower of the two vertically arranged processes, bearing at the margin three conical teeth and a row of three smaller granules within the margin, within this process is a bidentate protuberance corresponding to the upper of the two vertically arranged processes; basal view of the semicell triangular, angles broadly rounded, the margins furnished with one (rarely two) large conical teeth and two smaller granules on either side, and with two concentric rows of granules within the margin of either angle; sides in vertical view sharply retuse at the center. L. 37–39μ, w. 37–39μ, isth. 16μ. Pelee.

   Cellulae mediocres, quadratae aut aliquantum orthogoniae a fronte visae, sinu alto clausoque; semicellulae ad libram orthogoniae, tribus angulis apicales in dua prominentia brevia, truncata, a vertice disposita extentis, anguli basales late rotundati, tribus ordinibus concentricis granulorum praediti, ex quibus tria granula secundum utrumque marginem videri possunt; semicellula a vertice visa triangula, omne angulo, qui est idem cum angulo basale semicellulae, late rotundato, superimpositum et trans hunc angulum projectum est superius duorum prominentium a vertice dispositorum, tres dentes conicos et ordinem trium granulorum minorum in margine gerens, in hoc prominente est protuberatio bidentata superiori duorum prominentium a vertice dispositorum par; semicellula a basi visa triangula anguli late rotundati, margines uno aut raro duobus dentibus magnis conicisque et duobus granulis minoribus in utroque latere et duobus ordinibus concentricis granulorum in margine utrique anguli ornati, lateris a vertice visi in centro acute retusi. Long. 37–39μ, lat. 37–39μ, lat. isth. 16μ.
16. *Staurastrum polymorphum* Bréb. (Pl. V, Fig. 13). L. 28–30μ, w. 35–46μ, isth. 7–9μ. Haunk, Squaw Harbor, East Harbor.
17. *Staurastrum polytrichum* Perty var. **ornatum** Taft n. var. (Pl. V, Fig. 19). Cells slightly longer than broad, apices truncate instead of rounded; spines mostly curved, attached to

truncate, conical protuberances of the wall. Otherwise as in the species. L. minus spines 58μ, w. minus spines 55–57μ, w. plus spines 66–67μ, isth. 21μ, spines 4.5–5.5μ. Pelee.

Cellulae paulo longiores quam latae, apices truncati, non rotundati; spinae plerumque curvatae, protuberationibus truncatis conicisque muri aptae. Long. 58μ, lat. 66–67μ, lat. isth. 21μ.

18. *Staurastrum punctulatum* Bréb. var. *kjellmanii* Wille (Pl. V, Fig. 14). L. 39μ, w. 30μ, isth. 13μ. Kelleys Isl.
19. *Staurastrum sebaldi* Reinsch var. *ornatum* Nordst. (Pl. V, Fig. 15). L. 53μ, w. plus processes 96μ, w. minus processes 21μ, isth. 14μ. East Harbor.
20. *Staurastrum setigerum* Cleve (Pl. V, Fig. 18). L. 35–39μ, w. 39–46μ, isth. 11μ. Squaw Harbor, Wehrle, Haunk.

    Somewhat smaller than usual, but with the typical arrangement of spines.
21. *Staurastrum striolatum* (Naeg.) Arch. (Pl. V, Fig. 16). L. 19–21μ, w. 18–23μ, isth. 8μ. Wehrle, Haunk, Smith, Kelleys Isl.
22. *Staurastrum tetracerum* Ralfs (Pl. V, Fig. 17). L. plus processes 25–27μ, l. minus processes 10–11μ, w. plus processes 28–30μ, w. minus processes 7–9μ, isth. 5μ. East Harbor.

Sphaerozosma Corda 1835

Cells small, flattened, deeply constricted, with an open sinus, united in long, twisted filaments by means of short apical appendages. One chloroplast and one pyrenoid in each semicell.

1. *Sphaerozosma granulatum* Roy & Biss. (Pl. V, Fig. 23). Cell length 9–10μ, w. 9–11μ, isth. 4–5μ. Smith.

Spondylosium Bréb. 1844

Cells flattened, often deeply constricted, sinus open, variable in shape, apices truncate, concave or convex. Vertical view elliptic, tumid-elliptic or triangular. Cells united by the apposition of the apices into filaments.

1. *Spondylosium luetkemuelleri?* Grönblad. (Pl. V, Fig. 22). Cells of medium size, deeply constricted, sinus open. Vertical view elliptic, slightly tumid on either side. Cell wall smooth. Chloroplasts axial, each with one pyrenoid.

   These specimens have been doubtfully referred to *Spondylosium luetkemuelleri* on the basis of cell shape, size and chloroplast structure. Only two cells were seen and they were not united. Such peculiar shaped cells, if united in filaments, would dissociate readily. This may have happened in the writers collections.

Hyalotheca Ehren. 1840

Cells nearly cylindrical, length and breadth about the same, constriction broad and shallow, united into long filaments which are enclosed by a gelatinous sheath; each semicell with one axial chloroplast having radiating ridges and one pyrenoid.

1. *Hyalotheca mucosa* (Mert.) Ehr. (Pl. V, Fig. 20). Cell wall with two parallel rows of granules just within the apices. Filaments usually enclosed within a broad gelatinous sheath. Cell length 16–21μ, w. 18–20μ, isth. 16–18μ. East Harbor.

Desmidium Ag. 1824

Cells united in twisted filaments, usually with a broad gelatinous sheath, depressed, broader than long, with a distinct median constriction; 3–4 angled in vertical view (sometimes ovoid or citriform). One chloroplast and one pyrenoid in each semicell.

1. *Desmidium swartsii* Ag. (Pl. V, Fig. 21). Filaments triangular, twisted. Cell length 18μ, w. 44–46μ, isth. 37–41μ. East Harbor.

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Mainsprings of Civilization

Biological inheritance, cultural endowment and physical environment mould civilizations. None of these can be said to be more important than the others, as all are essential. In his fascinating new book, Mainsprings of Civilization, Professor Huntington impartially discusses the effects of these factors in the determining the course of civilizations. He introduces the term kith to describe a group of people closely knit together by blood and culture. Numerous kiths are discussed and compared in some detail. Special attention is given to the New England Puritans, Jews, Quakers, Junkers, the Parsis of India and the nomads of Arabia. He makes an especially interesting comparison of the Newfoundlanders and Icelanders. The latter have a more advanced culture, in spite of greater handicaps of physical environment. He believes the differences must be due largely to biological inheritance.

Numerous aspects of physical environment are discussed. Weather, diet, religion, climatic cycles, environmental cycles and their bearing on civilization are all given careful consideration. An interesting chapter deals with psychological reactions to weather. Discovery of the use of fire, the invention of windows, the better shelter and clothing have resulted in centers of progress moving from regions where optimum temperatures occur in winter to those where summer temperatures are the most favorable. The nutritive values of the diets of various nations are compared, in which respect Rumania and Russia are far below Italy, and even lower than Japan. Unusual topics, such as animal reproductive cycles and their possible relationship to amount of ozone in the atmosphere are given some attention. Climatic cycles and migrations are treated in some detail.

Mainsprings of Civilization is a comprehensive and entertaining presentation of up-to-date information in this immense field. It represents more than twenty years of research by the author and deserves to be widely read.—*D. C. Rife.*

Mainsprings of Civilization, by Ellsworth Huntington. 660 pp. John Wiley and Sons, Inc., New York. 1945. $4.75.

THE OHIO ACADEMY OF SCIENCE

ANNUAL REPORT OF 1945

REPORT OF THE EXECUTIVE COMMITTEE AND COUNCIL

The one important item handled by the Executive Committee and not reported below as a matter of Council action was the decision to omit the annual meeting for 1945. This decision was due to the restriction placed by the United States Government on meetings of large groups, for the purpose of conserving travel facilities. Since the war in Europe has ended it seems unlikely that another meeting will have to be omitted.

The Council has violated two constitutional provisions by holding only one meeting and by acting without a quorum. No doubt the members of the Academy will recognize that the national emergency made the irregularity unavoidable.

At the meeting in Columbus on April 7, 1945, President Carmen called the group to order and after the roll call a motion by Dr. F. H. Krecker that the sixteen members present act as a quorum was duly passed.

The possibility of providing a seal for use on certificates presented to participants in the Junior Academy was discussed at some length. Dr. Paul Rothemund moved that the Academy furnish certificates and that its official seal embossed over a gold star be used on these certificates.

This discussion led to the consideration of relations with the Junior Academy in general, with a suggestion that outstanding contributors to regional meetings be encouraged to take part in the state meeting and that certificates be awarded to all such participants rather than for the outstanding contributions at the state meeting. Dr. Krecker then proposed as an amendment to the motion that a committee of three be appointed to handle the matter of Junior Academy sponsorship. Dr. Blaydes seconded the amendment and the amended motion was passed.

The Council approved the principle that the Secretary and Treasurer should not leave office in the same year, in the interest of some continuity in the membership of the Executive Committee.

A long discussion of the relations of the Ohio Journal of Science and the Academy, dealing chiefly with payment for the publication of the Proceedings and the address of the Retiring President beyond the normal contribution of the Academy for the support of the Journal brought out a request from Dr. W. L. Evans for the report of the Editorial Board. This report showed that the Journal has felt the pressure of increased cost of publication, partly met by an increase in the contribution from the Ohio State University from $750.00 to $1000.00 per year. The total income from the Academy is uncertain until membership dues are paid, but should be between $900.00 and $1000.00. On motion of Dr. E. I. Yowell, seconded by Dr. Krecker, the Council approved payment for the publication of the two items for 1944. Dr. G. W. White then moved that the Council instruct the Academy Representatives on the Joint Administrative Board to take up the question of specific payment for these items in the future. Dr. Krecker amended to consider the entire question of Academy support of the O. J. S. and the amended motion was passed.

Dr. Krecker moved that all officers for 1944–45 be asked to continue in office for the coming year. The motion was duly seconded and passed unanimously.

The following members were elected to fellowship:

JAMES H. RODABAUGH	FRANCIS LEE UTLEY	CLARENCE WARD

The following new members were elected:

Myron A. Bachtell
John W. Bennett
Arthur H. Blickle
C. E. Cooper
Henry F. Bonner
Edward J. Dury
Albert J. Esselstyn
Lloyd W. Frost
Henry E. Gray
Lysle R. Kirk
J. R. Lockett
James F. Pepper
Newbell Niles Puckett
G. W. Prescott
Charles V. Reichart

Dr. Krecker proposed that a definite deadline be set for applications for grants from the research fund, all applications then to be considered together on a basis of relative merit.

The publication of obituary notices at intervals through the year was suggested in lieu of the usual inclusion of these notices in the annual report.

Dr. C. E. Taft reported on the Research Fund, mentioning a gift from Dr. Herbert Osborn of $100.00, designated for the purchase of a bond, and the Council unanimously voted its thanks to Dr. Osborn.

Respectfully submitted,

A. W. Lindsey, *Secretary.*

REPORT OF THE TREASURER

Columbus, Ohio, July 10, 1945.

To the Ohio Academy of Science:

I submit herewith a financial statement of the condition of the Ohio Academy of Science as of December 31, 1944. The books have been audited and the opinion of the auditor is herewith attached.

Respectfully submitted,

Clarence E. Taft, *Treasurer.*

Ohio Academy of Science Balance Sheet as at December 31, 1944

Assets

Current Expense Fund:			
Cash in Bank			$ 753 39
Interest Receivable			19.50
Bonds Owned:			
Federal Farm Loan 1944–45 (Cost)		$1,300.00	
War Savings Bond, Series F (Cost)		111 00	
Total Bonds Owned			1,411 00
Total Assets—Current Expense Fund			$2,183.89
Research Fund:			
Cash in Bank		$ 353 76	
*Banc-Ohio Securities Company Stock (Cost)		437 50	
Bonds Owned:			
*Port Hayes Hotel, Columbus, Ohio (Cost)	$1,300.00		
U. S. War Savings Bond—Series G	100 00		
Total Bonds Owned		1,400.00	
Total Assets—Research Fund			2,191.26
Total Assets			$4,375.15

*See Note, page 208.

Liabilities and Net Worth

Current Expense Fund:			
Liabilities:			
Accounts Payable			$ 210.29
Deferred Credit:			
1945 Dues Collected in 1944			15 00
Total Liabilities and Deferred Credits			$ 225.29
Net Worth:			
Ohio Academy of Science:			
Current Expense Fund Surplus		$1,958 60	
Research Fund Surplus		2,191 26	
Total Net Worth			4,149.86
Total Liabilities and Net Worth			$4,375.15

NOTE: Market values as follows:

Banc-Ohio Securities Company (25 shares)	$ 500.00
Bonds—Fort Hayes Hotel Company	780.00
Total	$1,280.00

Ohio Academy of Science Statement of Income and Expense
For the Year Ended December 31, 1944

Current Expense Fund

Income:			
Dues—Membership			$1,410 00
Grants for Research			165.00
Sale of Publications			12.56
Interest on Bonds			39.00
Miscellaneous			.10
Total Income			$1,626.66
Operating Expenses:			
Subscriptions—Ohio Journal of Science		$748 50	
Printing:			
Proceedings—Ohio Journal of Science	$195.29		
Other Printing	101.77		
Total Printing		297 06	
Research Grants		165.00	
Postage		24.51	
Office Supplies and Expense		23.85	
Expenses—Officers and Committees, etc.		5.78	
Secretary's Honorarium		100.00	
Auditing Expenses		15 00	
Bond of the Treasurer		5 00	
Safety Deposit Box Rent		3 60	
Bank Charges		2.89	
Total Operating Expenses			1,391.19
Excess of Income over Expenses			$ 235.47

Research Fund

Income:	
Cash Received	$ 243.98
War Savings Bond—Series G	100.00
Total Income	$ 343.98
Expenses:	
Grants for Research	125.00
Excess of Income over Expenses	$ 218.98

AUDITOR'S CERTIFICATE

COLUMBUS, OHIO, July 1, 1945.

To the Ohio Academy of Science:

GENTLEMEN:—In accordance with your instructions, I have audited the accounts and records of the Current Expense Fund of the Treasurer of the Ohio Academy of Science for the year ended December 31, 1944.

I did not audit the Research Fund.

I hereby certify that, in my opinion, the books and records kept on a cash basis are in accord with accepted accounting principles.

In my opinion, the accompanying Balance Sheet and the Statement of Income and Expense for the Current Expense Fund fairly presents the financial condition of the Ohio Academy of Science as at December 31, 1944, and the results of operations for the year ended at that date.

Respectfully submitted,

DANIEL W. SHONTING,
Certified Public Accountant.

REPORT OF THE JOINT ADMINISTRATIVE BOARD OF THE OHIO JOURNAL OF SCIENCE

COLUMBUS, OHIO, December 21, 1944.

To the Ohio Academy of Science:

A special meeting of the Joint Administrative Board of the Ohio Journal of Science was called on December 21, 1944, by the editor at the request of the business manager. The meeting was called to order by Chairman Dr. Snyder. Present were Drs. Snyder and White, representing The Ohio State University, and Drs. Evans and Anderson, representing the Ohio Academy of Science, and Drs. Blaydes and Miller, representing the Ohio Journal of Science.

Dr. Miller presented a partial financial report for Vol. 44, pointing out the fact that the cost of production of the current volume had exceeded the income for the year 1944. The manager requested the board to take the necessary action to avoid a repetition of a similar condition in the coming year.

Dr. White moved that the Ohio State University be requested to increase its contribution from $750.00 to $1000.00. This motion was seconded by Dr. Evans and was passed by a unanimous vote.

Dr. Evans moved that the Ohio Academy of Science be requested to contribute, beyond its normal payment of dues, a sum sufficient to continue the Journal for 1945, but not to exceed the additional amount contributed by the University. The motion was seconded by Dr. Anderson. In the discussion that followed considerable emphasis was placed upon the long history of the Journal and its position among scientific publications. The motion was unanimously adopted.

Dr. Snyder moved that the Editor and Business Manager continue to publish the Journal on the present basis, for the next three issues, pending the outcome of the request to be made of the University and the Academy.

Dr. Blaydes reported on available manuscripts and made a plea for additional papers. Each member of the board was urged to act as a committee of one to aid in securing desirable papers.

There being no further business to come before the board at this time, the meeting was adjourned.

Respectfully submitted,

JOHN A. MILLER,
Secretary of the Board.

COLUMBUS, OHIO, April 5, 1945.

The annual meeting of the Joint Administrative Board of the Ohio Journal of Science was held at Columbus, Ohio, April 5, 1945. The meeting was called to order by Chairman

Snyder. Present were, Drs. Snyder and White, representing the Ohio State University, Dr. Evans, representing the Academy, and Drs. Blaydes and Miller, representing the Journal. Dr. Anderson was unable to attend.

The minutes of the preceding meeting were read and approved.

It was moved, seconded and passed that Drs. Blaydes and Miller be retained as Editor and Business Manager respectively, for the year 1945–46.

Drs. Snyder and White were appointed to audit the accounts of the Journal for the year 1945–46.

Chairman Snyder called for a report from the Editor. Dr. Blaydes' report is herewith attached. The acceptance of the report was moved by Dr. Evans and seconded by Dr. White. The report was unanimously accepted.

The Chairman called for a report from the Business Manager. Dr. Miller's report was in the form of a financial statement for Volume 44 of the Ohio Journal of Science, a copy of which is herewith attached. It was called to the attention of the board that the cost of printing and distributing the Journal for the past year exceeded the income by $338.62.

The greatest single factor incident to the deficit was the decrease in revenue from the Academy. The Academy paid into the treasury of the Journal $1,211.43 in the year 1943 and $748.50 in the year 1944. The total income from all sources to the Journal during 1944 was $282.09 less than received by the Journal during the year 1943.

The simple facts are, the cost of production of the Journal as represented by the six issues of Vol. 44, has exceeded the income for the corresponding period of time. The Journal is not at the present time in debt; this is due to the fact that economies were effected in time to reduce costs to a minimum, and that sufficient operating capital had been accumulated to take care of just such an emergency. That capital has now been reduced to $127.69, an amount insufficient to meet expenses incurred during the first few months of each publication year.

FINANCIAL REPORT OF THE OHIO JOURNAL OF SCIENCE

Fiscal Year 1944

RECEIPTS:	
Balance from 1943	$ 466.31
University Allowance	750 00
Ohio Academy of Science—pro rata of Dues	748.50
Subscriptions	97.50
Sale of Back Numbers	38.80
Author's Payment for Plates	169.25
	$2,270 36
Check Outstanding (Mailing Dept., No. 422)	10 85
	$2,281.21
EXPENDITURES:	
Spahr and Glenn Co., Printing Vol. 44, Envelopes and Stationery	$1,760 36
Bucher Engraving Company	302 20
Postmaster	30.00
O. S. U. Mailing Department	15.86
Bank Charges	1 60
Clerical Assistance	41.00
Refund on Foreign Subscription	2.50
	$2,153.52
Balance on hand, March 1, 1945 (Huntington National Bank)	127.69
	$2,281.21

The business manager wishes to call attention to the board and through the board to the Academy the many difficulties which war conditions have precipitated. The Journal must look to the University and to the Academy to bolster its financial structure and insure its continuation. The University has responded by increasing its contribution as requested, from $750.00 to $1,000.00. I now present to the Academy the request as recommended by the board in their December meeting, that this organization assume its full financial obligation

in supporting the continuation of the Journal as the official organ of the society. It is anticipated that the Journal will require a minimum of $1,000.00 from the Academy to insure the publication of Vol. 45.

Dr. White moved the approval of the report of the Business Manager, the motion was seconded by Dr. Evans, and passed by a unanimous vote.

A motion presented by Dr. White, seconded by Dr. Evans and passed by the board is as follows: The board desires to express its appreciation for the faithfulness and efficiency of the Editor and Business Manager in perpetuating a commendable publication under the most trying circumstances.

There being no further business to come before the Board, it was adjourned.

Respectfully submitted,

JOHN A. MILLER,
Secretary of the Board.

REPORT OF THE LIBRARY COMMITTEE

COLUMBUS, OHIO, April 6, 1945.

To the Council of the Ohio Academy of Science:

The sales of publications amounted to $11.60, with nine cents sales tax. No sales were made during the first five months of the year and only ten sales were made during the entire year, five to individuals, three to book dealers and two to libraries.

A few foreign publications have been coming regularly on exchange and several others are now beginning to resume their sendings. Only this week the library received a very large shipment of Swedish publications and also a letter from the New York office of the Swedish government stating that facilities have now been made available for the resumption of shipments of exchange literature and that as soon as practical arrangements can be worked out we will be informed how to send our publications to Sweden. A letter from Chungking asks that we replace the National Central Library on our mailing list as the American postoffice has now resumed parcel delivery to China. It is very probable that similar letters will continue to come. Our part of the exchange can be carried out whenever it is safe to make shipments and whenever the censorship regulations will permit.

Respectfully submitted,

ETHEL MELSHEIMER MILLER, *Chairman.*

REPORT OF THE COMMITTEE ON NECROLOGY

I. ROLLAND DAVID FOX.

Rolland David Fox died suddenly October 24, 1943. At the time of his death, Professor Fox was Associate Professor of Bacteriology at Akron University, a position he had held since 1937. While still an undergraduate, he was made Student Assistant in the Department of Biology at Akron University. His studies were interrupted by World War I in 1918. However, he received his Bachelor of Science degree from the University in 1921. In that year he became a Graduate Assistant in Bacteriology, and in the following year was advanced to the rank of Instructor. In 1923 he was granted the degree of Master of Science, having completed "A Sanitary Survey of Summit Lake and Tributaries." He became Assistant Professor of Bacteriology in 1925, and Associate Professor in 1937, which position he held at the time of his death.

In 1926 he was appointed Director of the Division of Laboratories in the Akron Health Department, which he continued to occupy in conjunction with his position at Akron University. He had also been lecturer in bacteriology at Akron City Hospital since 1923. Holding a commission in the U. S. Army Reserve Corps, he attended army medical school at Carlisle Barracks during 1928 and 1930 and was awarded a certificate by that institution. He was U. S. Army Laboratory Officer, 103 General Hospital, in 1929.

Professor Fox was a member of the Ohio Academy of Science, Society of American

Bacteriologists, A. A. A. S., A. A. U. P., International Association Medical Museums, Ohio Association Sanitarians, American Chemical Society, and the American Commission for the Standardization of Biological Stains (Geneva). He was also district examiner for the American Medical Association.

He was one of the founders of Eta chapter of Phi Sigma at Akron University, and was a member of Phi Delta Theta fraternity, serving later as faculty advisor.

He was born at Peninsula, Ohio, on February 10, 1899. He is survived by his widow and one daughter, Frederica.

II. EUGENE WARREN MENDENHALL.

Eugene Warren Mendenhall died March 24, 1945, at Columbus, Ohio, after an illness of several weeks. He had been associated with the Ohio Department of Agriculture for 37 years, and at the time of his death was State Nursery Inspector.

Mr. Mendenhall was born in Knox County, Ohio, and was graduated by Ohio State University College of Agriculture in 1898. He was a member of the American Association for the Advancement of Science, and the Archaeological and Historical Society of Ohio, Entomological Society of America, as well as the Ohio Academy of Science.

Surviving members of his family are his wife, two daughters, two grandchildren, his brother, and two sisters.

III. JOHN R. PETERS.

The very promising geological career of John R. Peters was cut short early in July, 1943, when pneumonia caused his death in a week.

He was a most enthusiastic and capable young investigator, and his death is a sad loss both to friends and to science. He was especially interested in the broader aspects of stratigraphy and sedimentation. Sedimentary petrography, and the geology of the Arizona desert occupied most of his hours.

After a year and a half as a Graduate Assistant and junior colleague at the University of Cincinnati, Mr. Peters went to Earlham College as an Instructor in Geology on a temporary appointment. He became a great favorite of students at Earlham, and showed every indication of making good use of his academic opportunities. At the end of this appointment, he returned to Cincinnati as petrographer at the testing laboratory of the U. S. Army Engineers.

His research material and technical library has been preserved against the war release of one of his close geological friends who evinced an interest in seeing certain aspects of the work brought to publication.

Mr. Peters had received the degree of Bachelor of Science from the University of New Mexico. He had also attended the College of the City of New York, and North Carolina State College.

Respectfully submitted,

FREDERICK H. KRECKER,
Chairman, Committee on Necrology.

THE OHIO ACADEMY OF SCIENCE

CONSTITUTION AND BY-LAWS

(As revised at the Business Session of the Annual Meeting, April 14, 1939, and further Amended at the Annual Meetings of May 9, 1941, April 18, 1942, and April 29, 1943.)

Article I—Name

This organization shall be known as The Ohio Academy of Science.

Article II—Objects

The objects of this Academy shall be the promotion of research in the various departments of science and the diffusion of scientific knowledge.

Article III—Membership

1. *Classes of Members*—The Academy shall be composed of Members, Fellows, Honorary Fellows, Honorary Life Members, and Patrons.

2. *Members*—

a. *Members* shall be persons interested in scientific work. See By-Laws, Chap. I, Secs. 1 and 2.

b. *Life Members.* See By-Laws, Chap. III Sec. 2.

c. *Honorary Life Membership.* This membership is an honor to be conferred upon an active member of long standing who has rendered distinguished service to the Academy. Their number shall not exceed five. See By-Laws, Chap. I, Part 3.

3. *Fellows*—Fellows shall be members who are engaged in productive scientific work. See By-Laws, Chap. II, Secs. 1 and 2.

4. *Honorary Fellows*—Honorary Fellows shall be persons distinguished for their attainments in science, who are not active members of the Ohio Academy of Science, but whose life or work has some basic connection with Ohio. Their number shall not exceed twenty-five. See By-Laws, Chap. II, Secs. 3 and 4.

5. *Patrons*—Patrons shall be persons who have bestowed important favors upon the Academy. See By-Laws, Chap. II, Secs. 5 and 6.

6. *Voters*—Only Members, Fellows, and Patrons resident in Ohio shall be entitled to vote in the Academy. For Sectional Voting Privileges see Art. VIII, Sec. 3.

7. *Officers*—Only Fellows resident in Ohio shall be eligible to office and to membership in the Council of the Academy.

Article IV—Officers, Council and Committees

1. *Officers*—The officers shall be a President, a Vice-President for each Section organized, a Secretary, and a Treasurer.

2. *Council*—

a. The Council shall be composed of the President, Secretary and Treasurer of the Academy, the two most recent Past Presidents, the Chairman of the Trustees of the Research Fund, the Chairman of the Committee on Conservation, the Librarian, the Academy Representatives on the Joint Administrative Board and the Editor and Business Manager of the *Ohio Journal of Science*, the Vice-President and the Membership Committeeman of each organized Section as provided for in Article IV, Section 8d, and Article VI, Section 2b, and at intervals the retiring Secretary.

b. The Council shall have an Executive Committee consisting of the President, Secretary, Treasurer and two Council members elected by the Council.

c. For duties of Council, see Art. V, Sec. 6.

3. *Librarian*—The Academy Librarian shall be one of the members of the Library Staff of the College or University which is the depository for all Academy publications, including the exchanges. He shall be the chairman of the Library Committee. For appointment see Art. V, Sec. 7. For term of office see Art. IV, Sec. 8c.

4. *Historian*—The Academy Historian shall gather and preserve material pertaining to the history of the Academy.

5. *Committees*—

a. *Executive.* For membership see Art. IV, Sec. 2. For duties see Art V, Secs. 2, 5, and 7; and By-Laws, Chap. IV, Sec. 2a.

b. *Membership.* The Membership Committee shall consist of one Fellow from each Section of the Academy, who shall be elected by the Section. See Art. VI, Sec. 2b. For duties see Art. V, Sec. 8. For Chairman see Art. VI, Sec. 2b.

c. *Nominating.* The retiring Vice-Presidents of the various Sections shall constitute the Nominating Committee of the Academy for the Annual Meeting next following their retirement. For duties see Art. V, Sec. 3, and Art. VI, Sec. 1. For Chairman see Art. VI, Sec. 2b.

d. *Program.* The Program Committee shall consist of the Secretary, and the Vice-Presidents of the various Sections. See Art. V, Secs. 3, 4d, and 10.

e. *Library.* The Library Committee shall consist of the Academy Librarian and the two members of the Joint Administrative Board of the Ohio Journal of Science. See Art. V, Sec. 15c.

f. *Publications.* The Publications Committee shall consist of the Secretary of the Academy, who shall be Chairman, and the two Academy Representatives of the Joint Administrative Board of the Ohio Journal of Science. See By-Laws, Chap. V, Secs. 1–5.

g. *Conservation.* The Committee on Conservation shall consist of nine members elected in accordance with the provisions of Art. IV, Sec. 7, and Art. VI, Secs. 1 and 2. For duties see Art. V, Sec. 11.

h. *Necrology.* A Committee on Necrology shall consist of three members elected in accordance with Art. IV, Sec. 8b, and Art. VI, Secs. 1 and 3. For duties see Art. V, Sec. 12.

i. *Resolutions.* The Committee on Resolutions shall consist of three members elected in accordance with Art. IV, Sec. 8, and Art. VI, Secs. 1 and 2. For duties see Art. V, Sec. 13.

6. *Trustees of Research Fund*—Three trustees elected in accordance with Art. IV, Sec. 7, and Art. VI, Secs. 1 and 2, shall be designated Trustees of the Research Fund. For duties see Art. V, Sec. 14.

7. *Joint Administrative Board of the Ohio Journal of Science*—The Academy shall have two representatives on the Joint Administrative Board of the Ohio Journal of Science, elected in accordance with the provisions of Art. IV, Sec. 8c, and Art. VI, Secs. 1 and 2. For duties see Art. V, Sec. 15. See also By-Laws, Chap. V, Sec. 2.

8. *Terms of Office*—The President, Secretary, Treasurer, Trustees of the Research Fund, Members of the Committee on Conservation, Academy Representatives on the Joint Administrative Board, and the Members of the Committees on Necrology and on Resolutions shall be elected by the Academy at the Business Session of the Annual Meeting upon nomination by the Nominating Committee or from the floor of the Meeting in accordance with Art. VI, Secs. 1 and 2.

a. The President, Secretary, and Treasurer shall be elected annually. The President may not succeed himself.

b. The members of the Committee on Necrology and of the Committee on Resolutions, the Trustees of the Research Fund, and the members of the Committee on Conservation shall be elected for a term of three years; one member of the Committee on Necrology, one member of the Committee on Resolutions, one Trustee, and three members of the Committee on Conservation being elected each year.

c. The Academy Representative on the Joint Administrative Board of the Ohio Journal of Science shall be elected for a term of four years, one Representative to be elected biennially. They shall not be members of the Ohio State University.

d. Members of the Membership Committee, one from each Section shall be elected annually by the Sections. The President shall designate the Chairmen of the Membership and Nominating Committees.

e. The term of office of the Academy Librarian and Historian shall be determined by the Council.

f. *Vacancies.* See Art. V, Sec. 7b.

ARTICLE V—DUTIES OF OFFICERS, COUNCIL AND COMMITTEES

1. *President*—The President shall discharge the usual duties of a presiding officer at all General Sessions of the Academy and at all meetings of the Council. He shall keep himself constantly informed on the affairs of the Academy and on its acts and those of its officers; and he shall cause the provisions of the Constitution and By-Laws to be faithfully carried into effect. He shall also give an address to the Academy at the Annual Meeting of the year for which he is elected. See also Art. IV, Sec. 8d, and By-Laws, Chap. VII, Sec. 3b.

2. *Absence of President*—The duties of the President in case of his absence or disability shall be assumed by one of the Vice-Presidents designated by the Executive Committee of the Council.

3. *Vice-Presidents*—

a. The Vice-Presidents, elected as provided for in Art. VI, Sec. 2b, shall be Chairmen of their respective Sections.

b. They shall, with the Secretary acting as Chairman, constitute the Program Committee to arrange for the presentation of papers at the Annual Meeting.

c. Each retiring Vice-President shall transmit to the Secretary the names of the incoming Vice-President and Membership Committeeman of his Section.

d. The retiring Vice-Presidents shall constitute the Nominating Committee for the following year, as provided in Art. VI, Sec. 1. For chairman of the Committee see Art. IV, Sec. 8c.

4. *Secretary*—

a. The Secretary shall keep the records of the proceedings of the Academy, the Council and the Executive Committee. He shall maintain a complete list of the Members of the Academy with dates of their election to the different classes of membership and their separation from the Academy.

b. He shall cooperate with the President in attending to the ordinary affairs of the Academy, and shall have charge of the preparation, printing and mailing of circulars, blanks, notifications of election, announcements of meetings, etc.

c. Together with the Academy representatives of the Joint Administrative Board of the Ohio Journal of Science, he shall superintend the publication of the Annual Report and any other printing ordered by the Council or by its executive committee.

d. He shall be the chairman of the Program Committee as constituted in Art. IV, Sec. 5d.

e. After each Annual Meeting the Secretary shall send to each incoming member of the Council a copy of the Constitution; to each incoming Vice-President a list of the voting members of his Section, giving the latest address of each, and indicating which of these members are Fellows.

f. Upon retirement as Secretary, he shall automatically continue to serve as a member of Council for a term of one year.

5. *Treasurer*—The Treasurer shall have the custody of all the funds of the Academy. He may, at his discretion, deposit the funds in a bank (which is a member of the Federal Insurance Deposit Corporation), but he shall not invest them without authority of the Council or of its Executive Committee. He shall keep an account of receipts and disbursements in detail, and these accounts balanced as of the first of January of each year, shall be audited as hereinafter provided. See By-Laws, Chap. IV.

6. *Council*—

a. *Meetings*. The Council shall meet at least twice each year, once on the opening day of the Annual Meeting of the Academy (which shall be known as the Annual Meeting of the Council) and once on a date, set by the Executive Committee, at least sixty days prior to this Annual Meeting. Special meetings of the Council may be called by the President, or by any five members of the Council. See By-Laws, Chap. VII, Secs. 1 and 2.

b. *Duties*. The Council shall be the responsible executive and legislative body of the Academy, and shall have all power in keeping with such responsibility. See Art. IX; and By-Laws, Chaps. I, Sec. 2; II, Secs. 2, 4, and 6; IV, Sec. 2a.

7. *Executive Committee*—See Art. IV, Sec. 2b.

a. The Executive Committee is clothed with the executive authority and legislative powers of the Academy in the intervals between the regular meetings of the Council. No act of the Committee shall, however, remain in force beyond the next meeting of the Council unless ratified by the Council.

b. The Committee shall have the power to fill vacancies ad interim in any of the offices of the Academy.

c. It shall select and nominate to the Council for its action an Academy Librarian whenever necessary.

d. Other duties, see By-Laws, Chap. IV, Secs. 2a and 4.

8. *Membership Committee*—The Membership Committee shall seek to secure new members for the Academy, pass upon the qualifications mentioned in the applications, and make report with recommendations to the Council. As provided in Art. IV, Sec. 2, each Membership Committeeman is also a member of the Council.

9. *Nominating Committee*—See Art. IV, Sec. 5c and Art. VI, Sec. 1.

10. *Program Committee*—The Program Committee shall have charge of the arrangements for the papers and other details of the General and Sectional Sessions of each Annual and Special Meeting of the Academy, these papers and arrangements to be announced in the Official Program immediately before the Meeting. See Art. IV, Sec. 5d.

11. *Committee on Conservation*—The Committee on Conservation shall consider the various possibilities for the conservation of the natural resources of the State and the preservation of the native fauna and flora, including among other effective methods the formation of State Parks in areas of scenic, biologic, or geologic interest; it shall cooperate in all possible ways with other societies, institutions and State officers in the promotion of these objects. See Art. IV, Sec. 5g.

12. *Committee on Necrology*—The Committee on Necrology shall inform itself of any deaths among the members of the Academy, that may occur during the year; and it shall report these deaths to the Academy at the Business Session of the next Annual Meeting. It shall also prepare obituaries of such members for publication in the Annual Report and Proceedings of the Academy. See Art. IV, Sec. 5h.

13. *Committee on Resolutions*—See Art. IV, Sec. 5d. (In view of the suggestions which were made at the meeting of the Council on May 8, 1941, for enlarging the duties of this Committee, the wording of this Section has not yet been formulated.)

14. *Trustees of the Research Fund*—The three Trustees of the Research Fund shall have charge of the allotment and distribution of the income or of the principal of the Research Fund and of any additional gifts for research. See Art. IV, Sec. 6.

15. *Academy Representatives on the Joint Administrative Board of the Ohio Journal of Science*—These representatives shall have the following duties:

a. They are jointly responsible with the two representatives appointed by the President of the Ohio State University for the administration of the affairs of the Journal, and for the appointment annually of the Editor and Business Manager of the Journal. As provided in Art. IV, Sec. 2, they are members of the Council.

b. Together with the Secretary they shall constitute the Publications Committee of the Academy. This committee shall have charge of the preparation and publication of

the Annual Report, Proceedings, Special Papers and such other Academy papers as the Council may consider it desirable to publish. See By-Laws, Chap. V.

c. Together with the Academy Librarian they shall constitute the Library Committee, of which the Librarian shall be the chairman. This Committee shall advise with the Librarians of The Ohio State University on all questions arising in connection with the management of the Library of the Academy, deposited with The Ohio State University Library, and in connection with the distribution of the publications of the Academy.

Article VI—Nomination and Election of Officers

1. *Nominations*—The Nominating Committee shall nominate a candidate for each office to be filled: viz., annually, President, Secretary, Treasurer, one Trustee of the Research Fund, one member each of the Committees on Necrology and Resolutions, three members of the Committee on Conservation, and biennially, i.e., in the odd years, one member of the Joint Administrative Board of the Ohio Journal of Science.

2. *Elections*—

a. The nominations shall be submitted to the Academy at the regular Business Session of the Annual Meeting. See By-Laws, Chap. VII, Sec. 8b.

Election shall be by ballot; a majority vote of the Academy members present shall be necessary for election. For Quorum see Art. VII, Sec. 4.

b. Each regularly organized Section of the Academy shall elect by ballot its representative on the Membership Committee, who shall be a Fellow. This member in the following year shall become the vice-president of his section. The President shall then designate the chairman of the Membership and Nominating Committees. See Art. IV, Sec. 5b.

c. All officers shall enter upon their duties at the adjournment of the Annual Meeting.

Article VII—Academy Meetings

1. *Annual Meeting*—

a. A meeting of the entire Academy will be held each year, which shall be known as the Annual Meeting.

b. Its time and place shall be fixed by the Council subject to such instructions as may be determined by the Academy at the preceding Annual Meeting, and shall be announced by circular at least sixty days before the Meeting.

c. The details of the General and Sectional Sessions shall be arranged by the Program Committee and announced in the Official Program immediately before the Meeting. See By-Laws, Chap. VII, Sec. 3.

2. *Field Meetings*—Field meetings may be arranged by individual Sections or groups of Sections, upon approval by the Council or its Executive Committee.

3. *Special Meetings*—A special meeting of the Academy may be called by the Council or by the Executive Committee upon the written request of twenty Academy members.

4. *Quorum*—Fifty (50) members shall constitute a quorum for the transaction of business.

Article VIII—Sections

1. *Formation of Sections*—Members not less than ten in number may, by special permission of the Council, unite to form a Section for the investigation of any branch of science. Each Section shall bear the name of the science which it represents, e.g., The Section of Geology of The Ohio Academy of Science.

2. *Privileges of Sections*—

a. Each Section is empowered to perfect its own organization as limited by the Constitution and By-Laws of the Academy. It shall report its organization and officers to the Secretary. See Art. VI, Sec. 2b.

b. Each Section shall be represented on the Council by its Vice-President and its representative on the Membership Committee. See Art. IV, Sec. 2.

3. *Sectional Voting Privileges*—Members-elect of the Academy shall indicate on their

nomination blanks the Section in which they wish to have voting privileges. See Art. III, Sec. 6.

4. *Dissolution of Sections*—A Section may be dissolved by the Council at any time that such Section becomes inactive; or for sufficient reason at any other time, with the consent of a majority of the members of the Section.

Article IX—Amendments

Amendments to the Constitution shall be made in the following manner:

a. Initiation of an Amendment shall be by submission to the Secretary in writing of the content of the proposed amendment by 5 or more members of the Academy at least 90 days before the Annual Meeting.

b. Before the Annual Meeting the Secretary shall publish the proposed amendment in the Preliminary Announcement of the Annual Meeting, or in the Official Program, for the information of the members.

c. At least thirty days before the Annual Meeting the Secretary shall send a copy of the proposed amendment to each member of the Council for his ballot.

d. The ballots shall be returned to the Secretary and counted at the Annual Meeting of the Council. A three-fourths vote of the entire Council shall be necessary for approval.

e. The action of the Council shall be presented to the Academy at its succeeding Business Session for its approval. Reversal of the Council's action shall require a majority vote of the Academy members voting.

BY-LAWS

Chapter I—Nomination and Election of Members

1. *Nomination of Members*—Nominations for membership may be made at any time on blanks supplied by the Secretary. Such nominations shall be indorsed by two members who must be acquainted with the nominee and his qualifications for membership.

The Form of Nomination shall be as follows:

The Ohio Academy of Science

...., 19.....

To the Committee on Membership:

I desire to become a Member of The Ohio Academy of Science.

Name..

Address..

Major interests..

Section of the Academy in which Voting Privilege is desired..............................

....

Countersigned by Members:

....

....

Annual Dues $2.50.

This form properly filled out and accompanied by dues for one year is to be transmitted to the Secretary who shall turn all nominations over to the Chairman of the Membership Committee. This committee shall pass upon the qualifications mentioned in these applications, and make recommendations thereon to the Council.

2. *Election of Members*—Election shall occur by a majority vote of the Council members present at any regular meeting. Election to membership shall not be considered as completed until dues for the year are paid.

3. *Nomination of Honorary Life Members*—The nomination of Honorary Life Members shall be by the Executive Committee. Such nominations shall be transmitted to the Secretary of the Academy at least thirty days preceding the Annual Meeting and shall be presented to the Council for action at the Annual Meeting of the Academy. A three-fourths majority vote of members of the Council present will be necessary for election. See By-Laws, Chap. III, Part 2b.

CHAPTER II—NOMINATION AND ELECTION OF FELLOWS, HONORARY FELLOWS AND PATRONS

1. *Nomination of Fellows*—A suitable blank for the nomination of Fellows shall be supplied by the Secretary and shall be mailed to each Fellow of the Academy at least once each year. The form of nomination shall be as follows:

THE OHIO ACADEMY OF SCIENCE

NOMINATION FOR ELECTION TO FELLOWSHIP

(Must be in the hands of the Secretary at least 30 days before the Council meeting at which the nomination is to be voted on.)

Conditions of Fellowship

1. Fellows shall be members who are engaged in productive scientific work.—*Art. III, Sec 3, Constitution.*

Date

To the Council of the Ohio Academy of Science:

The undersigned Fellows have the honor to nominate

(Give name in full)

for election to Fellowship in the Ohio Academy of Science.

The nominee holds the following degrees: (Give institutions that conferred them)

is a member of the following scientific societies: (Give length of time a member of each)

and now holds the position of
in (Name of Institution)
located at

Respectfully submitted,
(Sgd.) , Fellow.
(Sgd.) , Fellow.

The following is a complete list of the important scientific papers published by the nominee, with exact references: (Use other side of this blank if necessary)

This blank properly filled out, endorsed by two Fellows of the Academy and accompanied by documentary evidence of the nominee's scientific achievements shall be transmitted to the Secretary, who shall present the nomination to the Council for action.

2. *Election of Fellows*—Election shall occur by three-fourths vote of the members of the Council present at any regular meeting.

3 *Nomination of Honorary Fellows*—At least 90 days before the Annual Meeting of the Council, the Secretary of the Academy shall notify the Vice-President of each Section of any vacancies in the ranks of Honorary Fellows, and shall mail to him two forms for the nomination of Honorary Fellows. Each Section through its Vice-President and Fellows may then nominate not more than two candidates. The form of nomination shall be as follows:

THE OHIO ACADEMY OF SCIENCE

NOMINATION FOR ELECTION TO HONORARY FELLOWSHIP

(Must be in the hands of the Secretary at least 30 days before the Annual Meeting of Council.)

Conditions of Honorary Fellowship

(1) Honorary Fellows shall be persons distinguished for their attainments in science, who are not active members of the Ohio Academy of Science, but whose life or work has some basic connection with Ohio. Their number shall not exceed twenty-five (Art. III, Sec. 4, Constitution.)

(2) Honorary Fellows shall be chosen
- a. from former members of the Academy for outstanding service in the scientific advancement of the Academy;
- b. from other persons who have made important contributions to the development of science in Ohio;
- c. from scientists who may have some other special connection with Ohio.

Date ....

To the Council of the Ohio Academy of Science:

The Section of .... of the Ohio Academy of Science has the honor to nominate ....

(Give name in full)

for election to Honorary Fellowship in the Academy. The nominee holds the following degrees: (Give institutions that conferred them) ....
is a member or former member of the following scientific societies: ....
....
and now holds the position of ....
in (Name of Institution) ....
located at ....

Respectfully submitted,
(Sgd.) ...., V P. of
the Section of ....

a. The nominee is distinguished for the following attainments in Science
b. The nominee's special scientific connections with Ohio are ....

c. The following is a list of the more important scientific papers published by the nominee, with exact references: ....

This form properly filled out and accompanied by documentary evidence of the nominee's scientific achievements, and by any other pertinent matter shall be transmitted to the Secretary by the Vice-President at least 30 days before the Annual Meeting of the Council.

As soon as possible thereafter, the Secretary shall send to each member of the Council a list of the nominees together with a brief digest of the reasons for the nominations.

Before the Council Meeting, the Executive Committee shall study the qualifications of the nominee, and shall present recommendations to the Council.

4. *Election of Honorary Fellows*—For election a three-fourths vote of the members of the Council present at the Annual Meeting shall be necessary.

5. *Nomination of Patrons*—The nomination of Patrons shall be by the Executive Committee, and shall be presented to the Council for action. See Art. III, Sec. 5.

6. *Election of Patrons*—Election shall occur by a three-fourths vote of the members of the Council present at its Annual Meeting. The Secretary shall notify the nominee of his election as Patron, and of the privileges accompanying it. See Art. III, Sec. 6.

CHAPTER III—DUES

1. *Dues*—The annual dues shall be two dollars and fifty cents ($2.50), payable in advance

2. *Commuted Dues*—

a. A single payment of twenty-five dollars ($25.00) shall excuse a member from all future annual dues and he becomes a Life Member. See By-Laws, Chap. IV, Sec. 2b.

b. Election by the Council to Honorary Life Membership in the Academy shall excuse a member from all future annual dues.

3. *Non-payment of Dues*—

a. Non-payment of annual dues shall deprive a member of the privileges of the Academy and of receiving its publications until such dues are paid.

b. An arrearage continuing over two years shall be construed as notification of withdrawal, which shall become effective after the member concerned has been so informed by the Secretary.

4. *Exemption from Payment of Dues*—

a. Patrons shall be exempt from payment of dues.

b. The Secretary, Treasurer, and Librarian shall be exempt from the payment of dues during the years in which they hold office.

Chapter IV—Finances

1. *Fiscal Year*—The fiscal year of the Academy shall be coincident with the calendar year.

2. *Investments and Expenditures*—

a. *Authorization.* No Academy funds shall be invested or expended, nor shall any debts be incurred without express sanction of the Council or of its Executive Committee, and the signature of the President. It is understood, however, that all ordinary expenses in connection with the Meetings have the permanent sanction of the Academy without special action. See Art. V, Sec. 5, Constitution.

b. *Investment of Commuted Dues.* The sum paid in commutation of annual dues shall be invested, and the interest used for the ordinary purposes of the Academy during the payer's life, but after his death the sum shall be transferred to the Research Fund.

3. *Bills and Vouchers*—Every creditor of the Academy must present to the Treasurer an itemized bill. The Treasurer (if he find the bill properly authorized) shall obtain the certification of the official incurring it, and shall thereupon pay the amount out of any funds not otherwise appropriated; the receipted bill shall be held as his voucher.

4 *Audit*—It shall be the duty of the Executive Committee of the Council to secure an audit of all financial accounts by a competent accountant, who shall report to the Executive Committee before the Annual Meeting.

5. *Bond of Treasurer*—The Treasurer shall give bonds in the sum of five hundred dollars ($500.00) with two good sureties, approved by the Executive Committee, for the performance of his duties and the safe keeping of the funds of the Academy.

6. *Honorarium of Secretary*—The Secretary shall receive an annual honorarium of one hundred dollars ($100 00) from which he shall pay for any clerical help employed by him.

7. *Ohio Journal of Science*—See By-Laws, Chap. V, Sec. 2b.

Chapter V—Publications

1. *Control*—The publications of the Academy shall be in charge of the Publication Committee. See Art. IV, Sec. 5f, Constitution.

2. *Official Organ*—The official organ of the Academy is The Ohio Journal of Science under the following terms of agreement:

1. The Academy shall pay to The Ohio Journal of Science one dollar and fifty cents ($1 50) for each subscription sent to member not in arrears from payment of dues.

b. The Ohio Journal of Science shall publish announcements of meetings, lists of publications for sale, etc., whenever the Academy desires. Such matter, however, may be restricted to one-half page of advertising space in any one issue. See Chap. V, Sec. 3.

c. The Ohio Journal of Science will print papers of from 300 to 1500 words presented at the Annual Meeting, provided such papers are submitted in typewritten form within two weeks from the time of adjournment of the Meeting, and have been passed upon favorably by the Publications Committee and the Editor of the Journal.

3. *Annual Report*—The Annual Report of the Academy including list of Officers, Secretary's report of the Annual Meeting, and such other matter as the Publication Committee may determine, shall be printed as a separate section or issue of the Ohio Journal of Science under the direction of the Publications Committee. The Constitution and By-Laws and a list of members shall be included in the Annual Report at five-year intervals.

4. *Special Papers*—Papers exceeding 1,500 words may be published at the discretion of the Publications Committee as a part of a series of Special Papers.

5. *Proceedings*—The Publications Committee shall at suitable intervals assemble the Annual Reports and the Special Papers into volumes of Proceedings of convenient size, paged consecutively in each volume, under the general title "Proceedings of the Ohio Academy of Science."

6. *Distribution*—

a. One copy of each publication shall be sent free to each Member, Fellow, Honorary Fellow and Patron, except as provided in By-Laws, Chap. III, Sec. 3a, and Chap. V, Sec. 2a.

b. The author of each Special Paper shall receive thirty (30) copies of his memoir.

7. *Publication of President's Address and Other Addresses*—

a. The President's address shall be published in the Ohio Journal of Science as soon as possible after the Annual Meeting, and shall not be published in another scientific magazine until it has appeared in the Journal.

b. Other addresses delivered before the Academy on invitation may be published in the Ohio Journal of Science.

Chapter VI—Research Fund

1. *Sources of Fund*—The Research Fund shall consist of moneys paid by the general public for publications of the Academy, of donations made by Patrons and others in aid of research, and of sums paid in commutation of dues according to By-Laws, Chap. IV, Sec. 2b.

2. *Donors*—Donors to this fund, to the sum of twenty-five dollars ($25.00) or more, shall be entitled without charge to publications subsequently appearing.

3. *Endowment*—The aim of the Academy shall be to accumulate a fund of which the income alone shall be used for the encouragement of research and for the publication of papers bearing upon the development of science in the State.

Chapter VII—Order of Business

1. *Procedure*—All meetings of the Academy and Council shall be governed by "Roberts Rules of Order."

2. *Meetings of the Council*—See Art. V, Sec. 6a, Constitution.

a. *Quorum and Order of Business.* The Council shall arrange its own order of business. A majority of the Council shall constitute a quorum.

b. *Annual Meeting.*

Agenda. The agenda of its Annual Meeting must include the receipt of the reports and recommendations of Standing Committees as follows: Executive Committee, Academy Representatives of the Joint Administrative Board, Program Committee, Trustees of the Research Fund, Committee on Conservation, Membership Committee.

3. *Annual Meeting of the Academy*—See Art. VII, Constitution.

a. *General Session.* The Academy shall have at least one General Session of its membership for the presentation of invited addresses and papers of general scientific interest.

b. *Business Session and Banquet.* There shall be a Business Session and Banquet of the Academy, the order of procedure being as follows:

(a) *Banquet.*

(b) *Welcome, Response and President's Address.*

1. Call to order by the President.
2. Welcome from the Host Institution.
3. Response for the Academy.
4. President's Address.

(c) *Business Session.*

1. Report from the Council.
2. Special Business.
3. Report of Committee on Necrology.
4. Report of Nominating Committee; and Annual Election.
5. Report of Committee on Resolutions.
6. Adjournment.

Chapter VIII—Amendments

These By-Laws may be amended by the same procedure as that stipulated for the amendment of the Constitution. See Art. IX, Constitution.

THE OHIO ACADEMY OF SCIENCE

MEMBERSHIP LIST

ABERNATHY, E. R.—*Psychology* .... State School for the Deaf, Columbus 15
ALDEN, J.—*Eugenics* .... 512 Burkhardt Ave., Dayton 3
ALDERMAN, O. A.—*Forestry* .... Experiment Station, Wooster
ALDRICH, J. W. (F. '41)—*Zoology* .... Dept. of Interior, Washington, D. C.
ALEXANDER, L. J.—*Botany* .... 343 Blessing Ave., Wooster
ALEXANDER, W. H. (F. '20)—*Meteorology* .... Normandie Hotel, Columbus 15
ALEXOPOULOS, C. J. (F. '41)—*Mycology, Plant Pathology* .... Kent State University, Kent
ALLISON, C. C.—*Plant Pathology and Genetics* .... Ohio State University, Columbus 10
ALTICK, A. R.—*Archaeology* .... Clark County Hist Soc. Museum, Memorial Hall, Springfield
AMSTUTZ, M. E.—*Entomology* .... 139 E. Liberty St., Ashland
ANACLETUS, SISTER M.—*Biology* .... St. Mary of the Springs College, Columbus
ANDERSON, A. C. (F. '39)—*Psychology* .... 30 Columbia Ave., Athens
ANDERSON, B. G. (F. '41)—*Physiology* .... West Virginia University, Morgantown, W. Va.
ANDRIX, N. W.—*Geology* .... 128 E. Royal Forest Blvd., Columbus 2
ANGELITA, SISTER M.—*Botany, Bacteriology, Zoology*, St. Mary of the Springs College, Columbus
ANGERER, C. A. (F. '42)—*Physiology* .... 264 E. Longview Ave., Columbus
ARENSON, S. B.—*Chemistry* .... University of Cincinnati, Cincinnati 21
ATWOOD, H.—*Botany* .... Box 746, Federal Bldg., Columbus
AUSTIN, R. C.—*Medical Science* .... 920 Fidelity Bldg., Dayton 2
AVERY, W. F.—*Physics* .... B. F. Goodrich Company, Akron 18

BABY, R. S.—*Physics, Anthropology* .... 5705 Brookpark Rd., Cleveland
BACHTELL, M. A.—*Agronomy* .... Experiment Station, Wooster
BACON, F. J. (F. '41)—*Botany* .... Western Reserve University, Cleveland
BALDUF, W. V. (F. '22)—*Zoology* .... 308 Harker Hall, Urbana, Illinois
BANGHAM, R. V. (F. '24)—*Anatomy, Entomology* .... 1004 N. Beaver St, Wooster
BARBOUR, G. B.—*Geology* .... University of Cincinnati, Cincinnati 21
BARR, D. R.—*Medical Science* .... Box 126, Grand Rapids
BARRETT, R. L.—*Mineralogy* .... Case School of Applied Science, Cleveland
BARROWS, W. M. (F. '20)—*Zoology* .... Ohio State University, Columbus
BARTLEY, F. (F. '44)—*Botany* .... Route No. 4, Circleville
BATTELLE MEMORIAL INSTITUTE—*Metallurgy and Fuels* .... 505 King Ave., Columbus
BAUER, A. H.—*Botany* .... Botany Bldg., State College, Pennsylvania
BAUMAN, H.—*Entomology and Animal Ecology* .... 1091 Jefferson Ave., Akron
BEAVER, W. C. (F. '30)—*Zoology, Botany, Medical Science* .... Wittenberg College, Springfield
BECK, J. R.—*Geography* .... 907 E. Main St., Kent
BENEKE, E. S.—*Botany* .... E. Chestnut St., Oxford
BENNETT, J. W.—*Anthropology* .... Ohio State University, Columbus 10
BERNHAGEN, R. J—*Geology* .... 706 Ohio Depts. Bldg., Columbus 15
BERRY, W. (F. '31)—*Geology and Botany* .... Duke University, Durham, N. C.
BEVAN, A. (F. '20)—*Geology* .... Box 1428, University Station, Charlottesville, Va.
BEYER, A. F., Jr.—*Paleobotany* .... 2068 Lewis Drive, Lakewood 7
BILLS, A. G. ('48)—*Psychology* .... 207 Lafayette Circle, Burnet Woods Station, Cincinnati 20
BINKLEY, L. E.—*Conservation and Ichthyology* .... Wittenberg College, Springfield
BLACKBURN, N. D.—*Entomology* .... Experiment Station, Wooster
BLAKE, F. C. (F. '20)—*Physics* .... Mendenhall Laboratory, O. S. U., Columbus 10
BLAYDES, G. W. (F. '35)—*Botany* .... B. & Z. Bldg., Ohio State University, Columbus 10
BLICKLE, A. H.—*Palaeobotany* .... Box 301, Athens
BODENBERG, E. T. (F. '37)—*Botany, Plant Physiology, Chemistry*, Dept. of Biology, Wittenberg College, Springfield
BOESEL, M. W. (F. '41)—*Entomology, Zoology* .... R. R. No. 2, Oxford
BOETTICHER, A. W.—*Biology, Botany* .... Ohio University, Athens
BOGNAR, E. J.—*Geology* .... 507 Oliver Bldg., Pittsburgh, Pa.
BOLE, B. P., JR. (F. '41)—*Ornithology, Mammology* .... 2717 Euclid Ave., Cleveland
BOND, R. H.—*Geology* .... Capital University, Columbus 9
BOORD, C. E. (F. '39)—*Chemistry* .... Ohio State University, Columbus 10
BORROR, D. J. (F. '36)—*Entomology, Ecology, Taxonomy of Odonata*, 1593 Minnesota Ave., Columbus 8

BOSSERT, R. B.—*Bacteriology* .... Ohio Wesleyan University, Delaware
BOWMAN, H. H. M. (F. '21)—*Botany, Zoology* .... Toledo University, Toledo
BOYD, M. J.—*Biochemistry* .... 2518 Cornell Place, Cincinnati 20
BRAND, LOUIS (F. '39)—*Mathematical Physics* .... University of Cincinnati, Cincinnati 21
BRANT, A. M. (F. '41)—*Mineralogy, Chemistry,* Lord Hall, Ohio State University, Columbus 10
BRAUN, A. F. (F. '22)—*Zoology* .... R. R. 13, Box 41c, Cincinnati
BRAUN, E. L. (F. '21)—*Botany* .... R. R. 13, Box 41c, Cincinnati
BRIDGHAM, C. M.—*Biochemistry* .... R. F. D. No. 1, North Jackson
BRIEF, B. J.—*Medical Science* .... 769 Kimball Place, Columbus
BRILL, H. C. (F. '40)—*Chemistry* .... Miami University, Oxford
BROMLEY, MRS. S. W. (F. '31)—*Botany* .... Scofieldtown Rd., Stamford, Conn.
BROWER, A. B.—*Medical Science* .... 60 Wyoming St., Dayton 9
BROWN, D. M.—*Taxonomy* .... 3310 Eleventh St. S. W., Canton 4
BROWN, H. D.—*Horticulture* .... Ohio State University, Columbus 10
BROWN, H. P.—*Entomology* .... Ohio State University, Columbus 10
BROWN, J. B. (F. '39)—*Chemistry* .... 1190 Lincoln Rd., Columbus
BRYANT, E. R.—*Biology* .... 117 Lakeside, New Concord
BUCHANAN, F.—*Ornithology* .... Amsterdam
BUCHANAN, K.—*Aeronautics* .... Box 148, Amsterdam
BUCHER, W. H. (F. '20)—*Geology, Physics* .... Columbia University, New York City
BUGELSKI, R., *Psychology* .... University of Toledo, Toledo
BULGER, J. W.—*Entomology, Plant Pathology, Zoology* .. 127 U. S. Court House, El Paso, Texas
BURGESS, W. M. (F. '42)—*Chemistry* .... University of Cincinnati, Cincinnati
BURNS, G. W.—*Plant Science* .... 2466 Wahl Terrace, Cincinnati 11
BURRELL, R. C. (F. '41)—*Agricultural Chemistry* .... Ohio State University, Columbus 10
BURTT, H. E. (F. '21)—*Psychology* .... Ohio State University, Columbus 10
BUSCH, K. G. A. (F. '36)—*Chemistry, Geology* .... Capital University, Columbus 9

CARLSON, F. A. (F. '38)—*Geography* .... 171 Oakland Park Ave., Columbus
CARMAN, J. E. (F. '20)—*Geology* .... Ohio State University, Columbus 10
CASTER, K. E. (F. '43)—*Paleontology* .... University of Cincinnati, Cincinnati 21
CECIL, RODNEY—*Entomology* .... P. O. Box 1330, Ventura, Calif.
CHADWICK, L. C.—*Horticulture* .... Ohio State University, Columbus 10
CHANDLER, D. C. (F. '41)—*Limnology, Fisheries, Biology* .... Stone Laboratory, Put-in-Bay
CHAPMAN, F. B.—*Natural Science* .... 1944 Denune Ave., Columbus 3
CHASE, S. W. (F. '24)—*Zoology* .... 2109 Adelbert Rd., Cleveland
CHILDERS, N. F. (F. '41)—*Plant Physiology, Horticulture, Chemistry,*
Ohio State University, Columbus 10
CHURCH, M. B.—*Mycology* .... Lyndon, Vermont
CINCINNATI UNIVERSITY GENERAL LIBRARY .... Cincinnati 21
CLAPP, P. S.—*Physics* .... 107 Ashbourne Rd., Columbus
CLARK, C. F.—*Mollusca, Fish, Aquatic Regulation* .... St. Marys
CLEVELAND MUSEUM OF NATURAL HISTORY .... 2717 Euclid Ave., Cleveland
COLE, L. E. (F. '43)—*Psychology* .... 111 S. Cedar, Oberlin
COLE, W. S. (F. '36)—*Geology* .... Ohio State University, Columbus 10
CONREY, G. W. (F. '24)—*Geology* .... Ohio State University, Columbus 10
COOPER, C. E.—*Geography* .... Box 385, Athens
COSSABOOM, R. T.—*Entomology* .... Baldwin-Wallace College, Berea
COSTELLO, R. E.—*Biology* .... 912 Latty St., Defiance
COTTERMAN, C. W.—*Genetics, Statistics* .... University of Michigan, Ann Arbor, Mich.
COTTINGHAM, K. C. (F. '29)—*Geology* .... 103 Riverview Park Drive, Columbus
COYLE, E. E. (F. '40)—*Botany, Zoology* .... College of Wooster, Wooster
CRIST, E. L.—*Botany* .... I. O. O. F. Bldg., Circleville
CRITTENDEN, H. W.—*Botany,*
Diet Medical Dept., Walseman Gen. Hospital, Camp Atterbury, Ind.
CROSS, A. T.—*Botany, Geology* .... 4800 Forbes St., Pittsburgh, Pa.
CROWELL, S.—*Zoology* .... Miami University, Oxford
CUNNINGHAM, H. A.—*Biology, Science Education* .... 227 N. Depeyster St., Kent
CUNNINGHAM, J. F.—*Zoology, Entomology, Botany* .... Ohio State University, Columbus 10
CURTIS, G. M. (F. '39)—*Medical Sciences, Biology* .... Ohio State University, Columbus 10
CUTRIGHT, C. R. (F. '30)—*Entomology* .... Experiment Station, Wooster

DAMBACH, C. A.—*Plant and Animal Ecology, Ent., Conservation,*
Ohio State University, Columbus 10
DARKER, G. D.—*Mycology* .... 19402 Maple Hts. Blvd., Maple Heights, Bedford P. O.
DAVIDSON, R. H. (F. '36)—*Entomology* .... Ohio State University, Columbus 10
DAVIS, A.—*Physical and Biological Science* .... Box 424, Columbus
DEAM, C. C. (F. '30)—*Botany, Forestry* .... Bluffton, Indiana

DEAROLF, K.—*Cave Fauna of U. S.* .... Public Library Museum, Dayton
DEICHMANN, W.—*Toxicology, Physiology, Pharmacology*. .... 527 McAlpin, Cincinnati 20
DELONG, D. M. (F. '21)—*Zoology, Entomology* .... Ohio State University, Columbus 10
DELOR, C. J.—*Medical Science*. .... 2074 Arlington Ave., Columbus
DETWEILER, F. G. (F. '42)—*Sociology*. .... Denison University, Granville
DEXTER, R. W. (F. '43)—*Biology, Ecology*. .... Kent State University, Kent
DICKERMAN, E. E.—*Zoology*. .... Bowling Green State University, Bowling Green
DICKERSON, L. M.—*General Biology, Genetics, Parasitology, Chemistry*, Soil Conservation Service, Spartanburg, S. C.
DIETZ, DAVID (F. '33)—*Astronomy, Physics*. .... 2891 Winthrop Road, Shaker Heights
DIETZ, H. F. (F. '32)—*Entomology* .... 2805 Monroe St., Wilmington, Del.
DILLER, O. D. (F. '40)—*Botany*. .... Experiment Station, Wooster
DOAN, C. A. (F. '39)—*Medicine and Biological Sciences*. .. Ohio State University, Columbus 10
DOAN, K. H.—*Ecology, Fish* .... Central Biological Laboratory, Winnipeg, Manitoba
DOBBINS, R. A. (F. '38)—*Botany and Entomology*. .... Ohio Northern University, Ada
DOCKERAY, F. C. (F. '24)—*Psychology* .... Ohio State University, Columbus 10
DODD, D. R.—*Botany, Geology, Soils* .... Ohio State University, Columbus 10
DONNER, H. F.—*Geology* .... Western Reserve University, Cleveland
DOW, C. L.—*Geography, Geology, Meteorology* .... 45 Maplewood Drive, Athens
DRAKE, C. J. (F. '21)—*Entomology* .... Iowa State College, Ames, Iowa
DREYER, J. F.—*Chemistry* .... 3314 Losanteridge Ave., Cincinnati 13
DREYER, W. A.—*Zoology*. .... University of Cincinnati, Cincinnati 21
DRILL, E.—*General Biological Science* .... 202 S. Campus, Oxford
DUNKLE, D. H.—*Vert. Pal* .... 2717 Euclid Ave., Cleveland 15
DUNLAP, H. L.—*Chemistry* .... 275 E. State St., Athens
DURY, E. J.—*Zoology* .... University of Dayton, Dayton

EBAUGH, W. C. (F. '40)—*Chemistry* Denison University, Granville
EDELMANN, A.—*Medical Sciences* .... 1588 Northwest Blvd., Columbus 8
EDGERTON, H. A. (F. '42)—*Psychology* . Natatorium, Ohio State University, Columbus 10
EDWARDS, L. F. (F. '32)—*Zoology* .... Ohio State University, Columbus 10
EDWARDS, R. L. (F. '32)—*Physics, Mathematics* .... Miami University, Oxford
EGGLESTON, H. R. (F. '41)—*Zoology* .... Marietta College, Marietta
EHLERS, G. M. (F. '40)—*Geology, Palaeontology, Zoology*, Museum of Paleontology, University of Michigan, Ann Arbor, Mich
EISEN, E. E.—*Geography* .... 126 Wilson Ave., Kent
ELLIOTT, R. (F. '33)—*Zoology, Medical Science* .... Ohio University, Athens
EMO, L.—*Physics* .... 1601 Perry St., Columbus
ENGLE, O. H.—*Zoology, Botany* .... 1409 Robinwood Rd., Alliance
ENGLISH, H. B. (F. '30)—*Psychology* .... Ohio State University, Columbus 10
ERF, H. A.—*Physics* .... 17355 S. Woodland, Shaker Heights
ESSELSTYN, A. J.—*Chemistry*. .... 110 N. Vine St., Westerville
EVANS, M. W. (F. '41)—*Agronomy*. .... Experiment Station, Wooster
EVANS, W. L. (F. '21)—*Chemistry* .... Ohio State University, Columbus 10
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STUDIES IN THE BIOLOGY OF THE LEECH IX[1]

THE GROSS NERVOUS SYSTEM

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INTRODUCTION

To the student of animal behavior a knowledge of the nervous system of the organism under observation is of utmost importance. Experimental evidence has provided valuable data regarding the arrangement of the functional components of the action system of this organism but in a comprehensive analysis of behavior this source of information is inadequate. A review of the work of earlier investigators is informative and applicable in so far as they have revealed the anatomical organization of the nervous system of annelids in general. The work of Whitman, Bristol, and others is especially pertinent at this point inasmuch as they were concerned with *Hirudinea*, and in the case of the latter, with a form closely related to the species herein described. I shall undertake in this and subsequent papers to present the macroscopic and microscopic anatomy of the leech *Haemopis marmoratis* (Say).

I have omitted from the following discussion any details of a cytological and histological nature except where imperative. This phase of the study is now under careful consideration and will appear at an early date. The writer has attempted to avoid a lengthy description of details in instances where a suitable illustration can best serve.

METHODS

In previous papers (1943–44) the writer has outlined in detail new staining methods and modifications applicable to the leech. In general it may be repeated here that the gold chloride and silver nitrate impregnation methods provide the basis for subsequent nerve differentiation. Counterstaining with phosphotungstic acid and Masson's stain has advantages in certain instances where tissue differentiation is also desirable. All of the illustrations, except where otherwise noted, are tracings of projected sections. Reconstructions are produced from serial sections employing micro-projection equipment.

THE NERVOUS SYSTEM OF HAEMOPIS MARMORATIS

The gross nervous system of *Haemopis marmoratis* is for convenience described as being composed of the following four divisions. (1) The central system, (2) the peripheral system, (3) the subepidermal system, and (4) the visceral system.

THE CENTRAL NERVOUS SYSTEM

The central system consists of an anterior cephalization contained in the head region, a series of segmentally arranged ganglia connected by the ventral nerve

[1]*Haemopis marmoratis* (Say).

cord in the body region, and a caudalization found in the anal region. The anterior division of this system is composed of a mass of neuromeres more or less completely fused, and forming a collar about the esophagus. The dorsal mass is referred to as the brain or supra-esophageal ganglion. This portion is connected with the ventrally located sub-esophageal ganglia by the circum-esophageal connectives (Plate No. II, Fig. 1). This anterior cephalization represents six neuromeres. The criteria used in this determination conforms with that employed by Whitman (1895) and Bristol (1899) in similar studies involving the metamerism of *Clepsine* and *Nephelis*, respectively.

The anal or caudal ganglia is composed of eight neuromeres. In this region fusion and distortion has taken place but not to the same degree as in the head region just described. Here the number and arrangement of the contributing neuromeres can be easily distinguished. A reconstruction from serial sections, using the same criteria as before, unmistakably established the boundaries of each ganglion. The number and position of lateral nerves arising from this caudal mass corresponds with the capsular number and arrangement. There are eight pairs of lateral nerves, one pair emanating from each determined ganglion.

Lying between the above described terminal portions are twenty ganglia. The first eighteen are metamerically arranged, though at the extremities not equally spaced. The nineteenth and twentieth ganglia are contained within somite XXV. The first three and the last two ganglia in the ventral chain are smaller than the the ganglia of the mid-body region. The ganglia of the ventral chain are joined together by a pair of nerve trunks extending from the sub-esophageal ganglion to the anal ganglia (Plate No. I, Fig. 1). The entire ganglionic chain is contained within the ventral blood sinus.

A Typical Neuromere

The knowledge of the capsular arrangement of the nerve cell bodies in a typical ganglion is a prerequisite to the analysis of either the "brain" or "anal ganglia." The nerve cell bodies of a ganglion are arranged, in general, in six primary clusters. Two such groups occupy a median ventral position while the remaining four are dorso-laterally placed. Near the center of the ganglion the cells of the latter are found to extend to a ventral-lateral position. It is only in the brain and anal ganglia that a shift from this general arrangement is noted. The number of primary capsules, however, even at the extremities remains constant. Each primary capsule is composed of numerous secondary cell clusters.

Of equal importance in defining the limits of a neuromere are the extra capsular cell bodies. Metamerically arranged cell bodies of this type may be listed under one of two classes. First, those whose cell bodies lie within the plexiform substance and whose processes enter the capsular area. The "Gross" motor nerve cell previously described by Krawany (1905), Retzius (1892), Smallwood (1930) and others is an example of this type. The cell body of the "Gross" cell is outside the capsule and usually contained within the plexiform or fibrous portion of the ganglion. These are giant multipolar motor cells. (Illustrated Plate I, Fig. 1, Miller 1944).

In *Haemopis*, as in *Nephelis* (Bristol) and *Clepsine* (Whitman) each body neuromere contains two "median nerve cells." The cell body of this type of "giant" cell is spindle shaped. (Plates Nos. II and III, Figs. 3 and 5). The cell bodies lie within the plexiform or fibrous portion of the ganglion in a ventral-median position. The number and arrangement of the "median nerve cell bodies" is especially valuable as an aid in determining the limits of the neuromeres contributing to the "anal ganglia."

A second class of extra-capsular nerve cells are these whose processes do not enter the capsular area. Two examples of this type of cell are found in the central system, both are "giant" bipolar cells.

The first example, Leydig's cell (Herman 1875) in addition to being outside the capsular aggregation has no connection with the plexiform or fibrous portion of the cord. It is present throughout the ganglionic chain, varying in position from between the axis of the lateral nerves of a midbody ganglion to an extra ganglionic position in the head and anal region. In the midbody region the processes of this cell leave the ganglion by way of the lateral nerves. The metameric consistency of Leydig's cell makes it a useful landmark in those areas where congestion of neuromeres has occurred. (Plate No. III, Fig. 1).

A second example of "giant" cell belonging to class two is the "colossal axial cell." (Plate No. III, Fig. 4). This type of cell will be mentioned only briefly inasmuch as it does not afford a basis for determining the limits of a neuromere. The nucleus of this cell lies about midway between the ventral ganglia within each of the two ventral connectives. The processes extend both anteriorly and posteriorly in the fibrous portion of the ventral cord. There is an experimental basis for inferring that the processes of the axial cell extend beyond the adjacent ganglia. Although my preparations clearly show the presence of inter-ganglionic processes continuing through the ganglion, a single fiber cannot be traced with accuracy over so great a distance.

I have excluded from the discussion at this time the extraganglionic neurons of the visceral and subepidermal systems. Reference to these systems will be made later in the paper.

Each body segment in *Haemopis marmoratis* is represented in the nervous system by a ganglion. The number of segments is established as XXXIV. The distribution of the ganglia and segments is illustrated in Table No. 1. The ganglionic centers of the nervous system are simple repetitions, element for element, the "brain" and "anal ganglia" not excepted. Plate Nos. I and II, Figures 1, 2, 3, illustrate the numbers and arrangement of the ganglia together with their lateral nerves for the head, body and caudal regions.

The Head Region

The head region is designated as that portion of the organism which includes the entire anterior cephalization. In *Haemopis marmoratis* this region extends from somite I through somite VI. This region includes the first eleven annuli.

The supra-esophageal ganglion or brain rests upon the dorsal wall of the pharynx at the level of the caudal annulus of somite V. Beneath the pharynx at the level of the second annulus of somite VI lie the sub-esophageal ganglia. The esophageal connectives extend laterally and ventrally from the brain. They are directed caudad, traversing the first annulus of somite VI, and join the sub-esophageal ganglia beneath the pharynx.

In order to determine the number of neuromeres comprising this region it is essential that the capsular number and arrangement as well as the peripheral nerves emanating from it be established. Nerve trunks one and two arise together from the anterior surface of the lateral connectives. They arise as parallel nerves proceeding anteriorly some distance before separating. The nerve cell bodies comprising the capsules of the first neuromere are located on the dorsal surface of the brain. The capsules of nerve two are located on the connectives. The third and fourth pair of lateral nerves arise near the vortex of the sub-esophageal ganglia. Both pairs divide into a dorsal and ventral branch some distance anteriorly. The fifth pair of nerves arises near the center of the sub-esophageal ganglia. These nerves proceed anteriorly to the level of the connectives as a single trunk before dividing into a dorsal and ventral nerve root. The sixth and last pair of nerves emanating from the head region, arise from the apical end of the sub-esophageal ganglia. Members of this pair divide soon after leaving the body of the ganglia (Plates Nos. I, II, Fig. 1).

The number of neuromeres is thus determined to be six. Whitman (1895) established the same number and essentially the same position for the neuromeres

in *Clepsine.* Bristol (1899) found a like number and position to prevail in *Nephelis lateralis.*

The Body Region

A complete body segment or somite consists of five annuli. Associated with each somite is a single ganglion located within the ventral blood sinus. In *Haemopis marmoratis*, eighteen ganglia are contained within the body region. The limits of this region are herein defined as somites VII through XXIV.

Extending caudad from the sub-esophageal ganglia are two parallel nerve trunks. Each nerve trunk is surrounded by a connective tissue sheath. The two main trunks are contained within an envelope which is continuous throughout the central nervous system. It has been previously stated that the ventral nerve cord, as well as the segmentally arranged ganglia of the ventral chain are contained within the ventral blood sinus. The first ganglion (most cephalad) of the ventral chain is contained within the first annulus of somite VII. This is the first in a series of segmentally arranged ganglia of the body region. It is actually the seventh ganglion of the animal and although smaller in size than a mid-body ganglion it is complete in every respect. From each ganglion of the body region arise two pairs of lateral nerves. The ganglia of the ventral chain, exclusive of the caudal region, occupy the first annulus of each somite.

The Anal Region

The anal region includes somites XXV through XXXIV inclusive. Somite XXV consists of two annuli, annulus 102 and 103 respectively. Somite XXVI includes annuli 104 and 105. Somite XXVII is represented by a single annulus, 106. Somites XXVIII through XXXIV are contained in the sucking disc.

Ganglion XIX of the ventral chain (the twenty-fifth of the entire series) is located within annulus 102. The XXth ganglion is contained in annulus 103. The last two mentioned ganglia are smaller than typical midbody ganglia. Each, however, contains six primary capsular aggregations of nerve cell bodies. Ganglion XX differs from the other unfused ganglia of the ventral chain in that it gives rise to a single pair of lateral nerves in deference to the usual anterior and posterior pair.

The "anal ganglia" is composed of eight neuromeres, and occupies the posterior third of annulus 103, all of annulus 104 and the anterior part of annulus 105. The components of this compressed and fused ganglia retain their fundamental characteristics and are plainly resolvable. The exact number and limits of each neuromere is established through reconstruction of the region and presented in Plate No. 11, Fig. 3.

In the preceding pages I have stated that the adult *Haemopis marmoratis* is divisible into thirty-four segments. This number is characteristic for *Hirudinea* in general as the work of many previous investigators will testify. The results of this study confirm earlier work in this respect, but I submit in deference to some that the allocation of specific segments to a particular body region cannot be made by generalizing from a study of a species or two.

EXPLANATION OF PLATE I

FIG. 1. This is a dorsal view of the anterior portion of *Haemopis* illustrating the metameric position of the central and peripheral nervous systems within the first seven somites. The somites are indicated by Roman numerals and the annuli are numbered in Arabic figures. The paired peripheral nerves are illustrated on the right and are numbered by Roman numerals. (The nerves on the left side are omitted for clarity).

ABBREVIATIONS

sub. eso. g. . . . . subesophageal ganglia supra. eso. g. . . . . . supraesophageal ganglia
v.n.c. . . . . ventral nerve cord

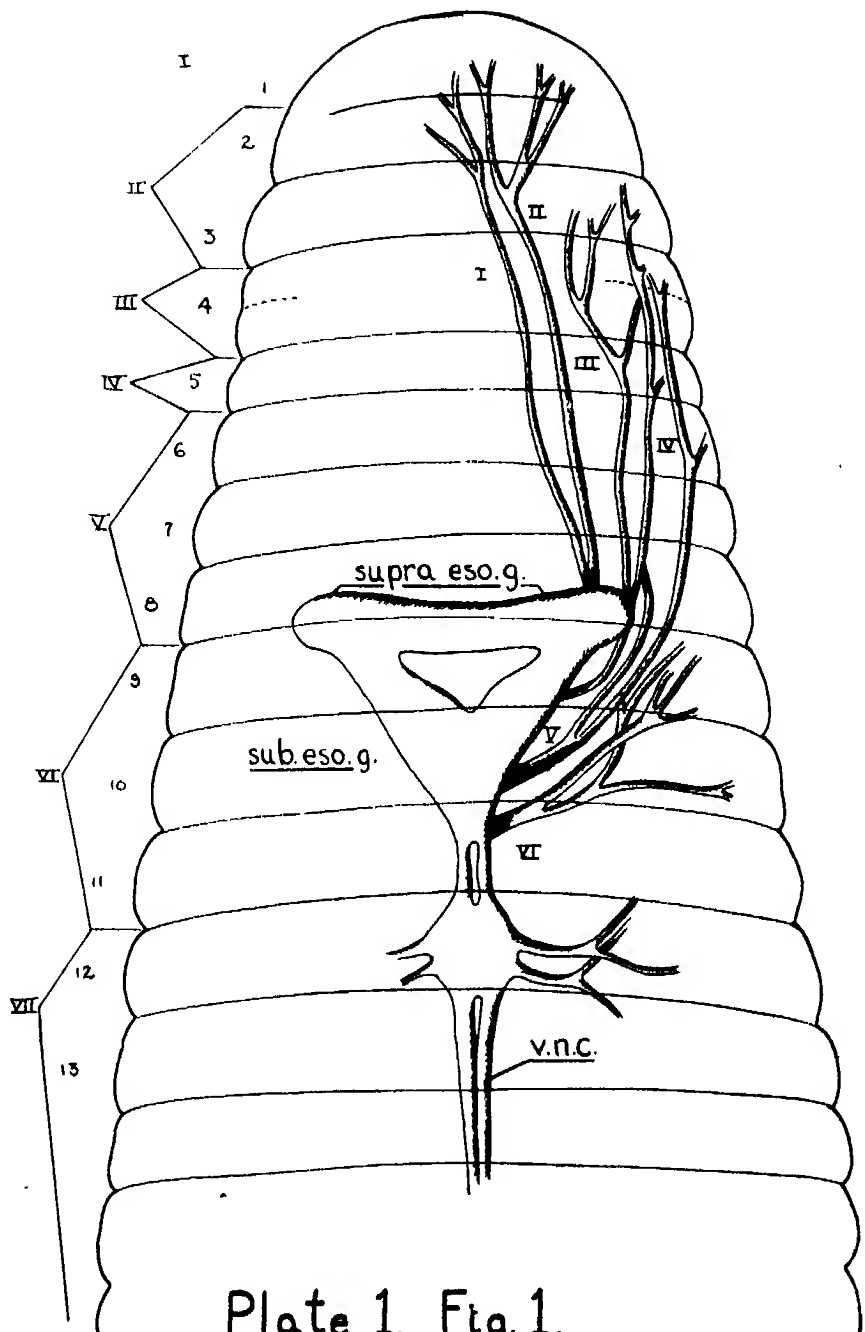
I
1
2
II
3
III
4
IV
5
6
V
7
8
9
VI
10
11
12
VII
13
II
I
III
IV
supra eso.g.
sub.eso.g.
V
VI
v.n.c.

Plate 1. Fig. 1.

EXPLANATION OF PLATE II

FIG. 1 This is a reconstruction of the nervous system of the head region as viewed from the lateral aspect. The central, peripheral and visceral systems are included in a single drawing to illustrate their relationship as well as their metameric position The origin and general distribution of the peripheral nerves emanating from the right side of the collar and subesophageal ganglia are illustrated and numbered The first ganglion of the ventral chain is included in this illustration and occupies the first annulus (No 12) of somite VII. The visceral nervous system, as viewed from the right side, shows a ganglionic mass, circumesophageal trunks and anterior-posterior fibers

FIG 2 This is a lateral view of the posterior portion of *Haemopis* as reconstructed from serial longitudinal sections. The anatomical relation and metameric position of the ganglia and peripheral nerves in the caudal region are illustrated The ganglia of the ventral chain are numbered in Roman numerals from I to XX inclusive. The six ganglia contained in the head region and the eight ganglia comprising the "anal ganglia" together with the twenty ganglia of the ventral chain constitute the thirty-four ganglia of the leech. (Ganglia XX of the ventral chain is therefore the twenty-sixth ganglion of the leech) A single pair of lateral nerves emanates from ganglion XX. Eight pairs of lateral nerves, one from each contributing ganglion, extend from the "anal ganglia." The five anterior pairs are directed caudad, the posterior three pairs unite in forming a large caudal nerve trunk.

ABBREVIATIONS

anal. g	anal ganglion	sub. eso. g	subesophageal ganglia
ant. n	anterior nerve	v b. s	ventral blood sinus
d. l. cap	dorso-lateral capsule	vis. f.	visceral fibers
l. n. s	lateral nerves	vis g	visceral ganglion
med n c.	median nerve cell body	vis. t	visceral trunks
post n	posterior nerve		

Fig 1.

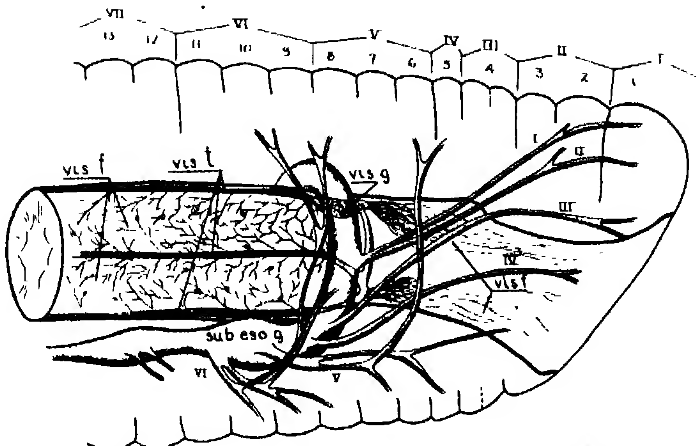

Fig. 2

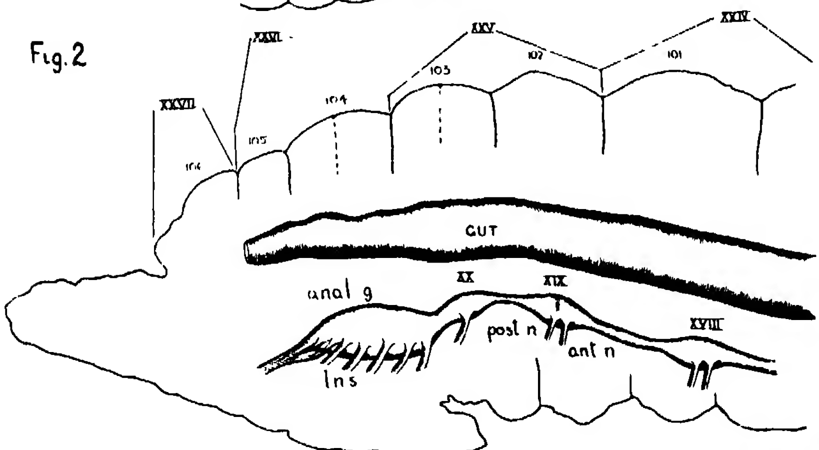

Fig. 3.

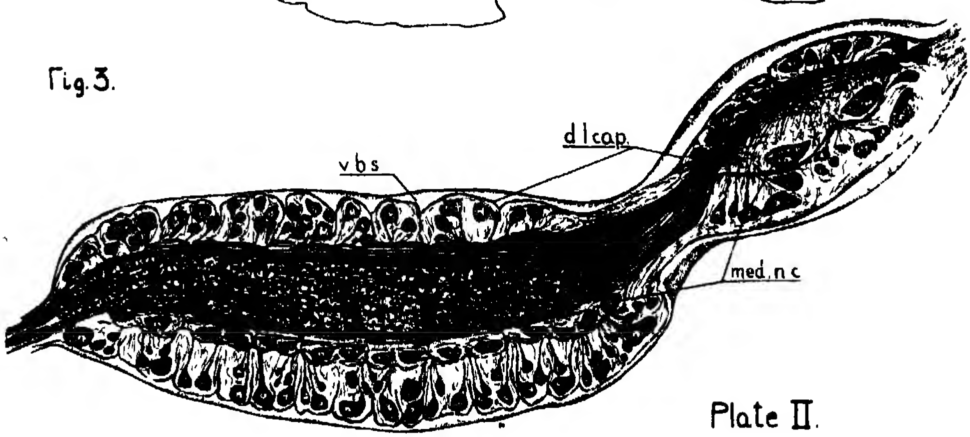

Plate II.

EXPLANATION OF PLATE III

Note.- The drawings in Plate III are traced from projected sections. Each with a magnification of 50 diameters.

FIG 1. This is a horizontal longitudinal section through the dorsal hemisphere of a mid-body ganglion. A portion of each of the dorsal paired capsular areas (d. p cap) is illustrated Many fiber tracts, nerve cell bodies and processes have been omitted in order to illustrate the general pattern Leydig's cell (L. c.) is shown in the extra-capsular area between the anterior and posterior lateral nerves

FIG. 2. This is a cross-section through a mid-body ganglion at the level of the posterior nerve.

FIG. 3. This is a cross-section through a mid-body ganglion just anterior to the anterior nerve.

FIG. 4 This is a cross-section through the ventral nerve cord about mid-way between ganglia. This section was selected to illustrate the cell body of a colossal axial cell. (c a. c)

FIG. 5 This is a cross-section of a mid-body ganglion at the level of the cell body of a median nerve cell. (med. n. c.)

ABBREVIATIONS

ant.	anterior	l f	longitudinal fibers
ant. l n	anterior lateral nerve	l n	lateral nerve
a p t.	anterior-posterior fiber tracts	med v. cap	median ventral capsule
c. a. c.	colossal axial cell	med. n. c	median nerve cell
d. l. f	dorsal longitudinal fiber tracts	plex. sub.	plexiform substance
d p cap	dorsal primary capsule	post	posterior
ex. cap	external capsule	post l. n	posterior lateral nerve
int cap.	internal capsule	v b s	ventral blood sinus
L c.	Leydig's cell	v. l. b	ventral longitudinal fibers

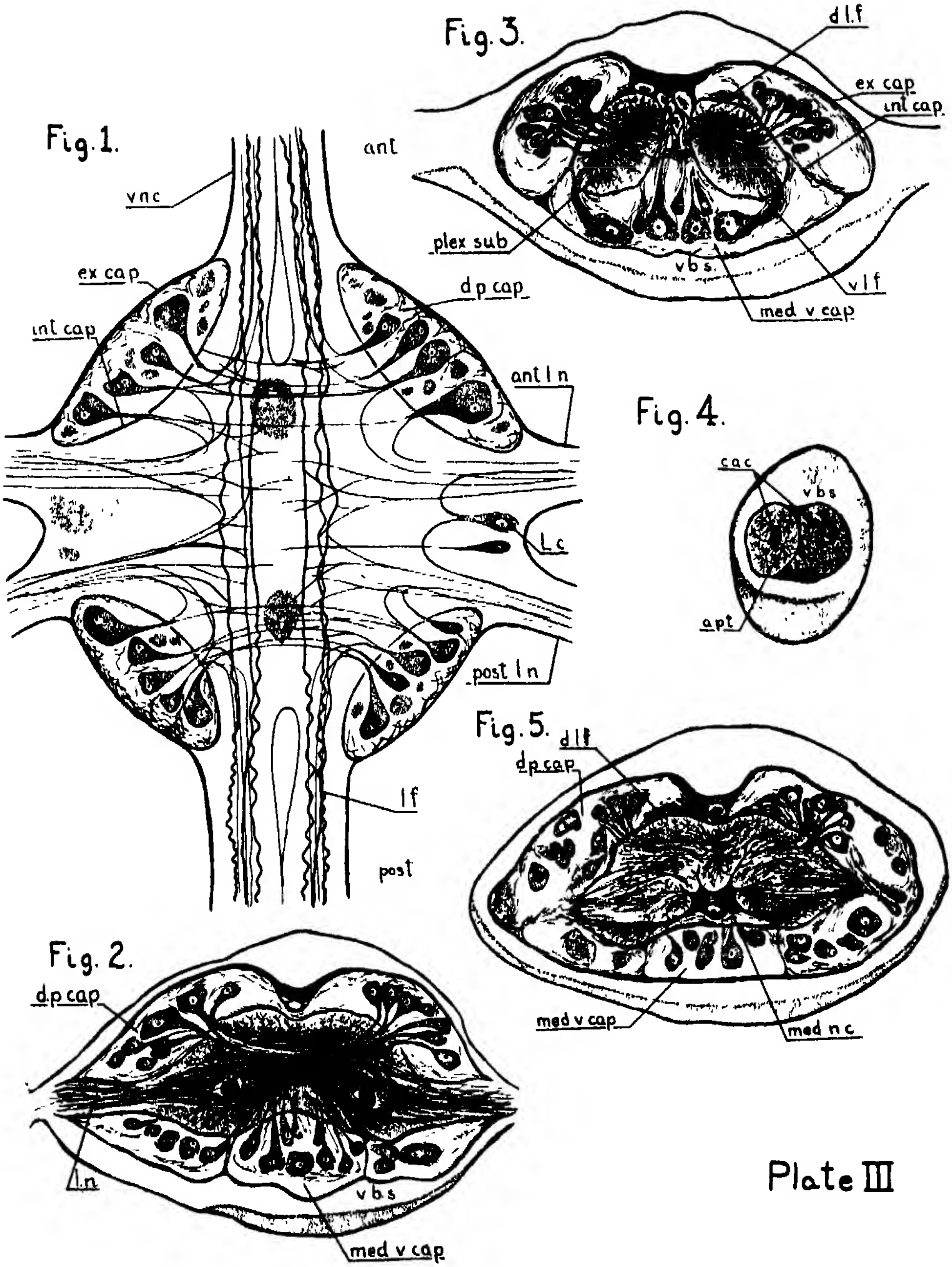
Fig. 1.
vnc
ant
ex cap
int cap
d p cap
ant l n
L c
post l n
l f
post
Fig. 2.
d p cap
l n
v b s
med v cap
Fig. 3.
d l f
ex cap
int cap
plex sub
v b s
v l f
med v cap
Fig. 4.
c a c
v b s
a pt
Fig. 5.
d l f
d p cap
med v cap
med n c

Plate III

I have defined three regional divisions for the leech under consideration, namely, the head region, the body region and the anal region. In each division the number of neuromeres correspond to the number of segments, as follows, the head region six; the body region eighteen; and the anal region ten. I classify however, the first two ganglia (XXV and XXVI) of the anal region as ganglia of the ventral chain exclusive of the "anal ganglia." Thirty-four ganglia are thus determined and distributed, one for each body segment.

TABLE I

Head Region consists of:	Head Region contains:
Somites I to VI incl.	Ganglia I to VI incl.
Body Region consists of:	Body Region contains:
Somites VII to XXIV incl.	Ganglia VII to XXIV incl.
Anal Region consists of:	Anal Region contains:
Somite XXV	Ganglia XXV and XXVI
Somite XXVI	Ganglia XXVII to XXXIV
Somites XXVII to XXXIV	No ganglia

THE PERIPHERAL NERVOUS SYSTEM

In this system are included the paired lateral nerves and their branches emanating from the ganglionic masses of the central nervous system. From each ganglion of the body region there arises two pairs of lateral nerves. They emerge from the lateral border of the ganglia extending in a horizontal plane at right-angles to the long axis of the body. The anterior pair emerges near the center of the ganglion, the second pair just posteriorly to the first. Each lateral nerve separates a short distance from the ganglion into a dorsal and ventral branch. The divisions and subdivisions of these lateral nerves innervate a portion of the preceding segment as well as the segment in which they arise.

The nerves of the anterior pair are not single nerves as careful study will disclose. Each one is formed by the fusion of a dorsal and ventral root. The fibers of the dorsal and ventral root combine to form a single nerve trunk at the point where the lateral (anterior) nerve leaves the body of the ganglion. There is no evidence that the posterior pair arises in the manner just described for the anterior pair. It might be of interest to state that in certain leeches, *Clepsine* for example, there are three pairs of lateral nerves per segment. It has been suggested by some writers that in those leeches possessing but two pairs of lateral nerves per segment, that the anterior pair represents a fusion of the first two in those forms having three pairs per segment.

Exceptions to the above described pattern in the midbody region are found in the head and anal regions. In the head region a single pair of lateral nerves emanates from each of the first five established ganglia. The branches of these five extend to the anterior margin of the prostomium and oral sucker. From the sixth and last ganglion of the head region emerge two pairs of lateral nerves. These innervate the sixth segment in a pattern comparable to that described for a midbody segment.

In the anal region ganglion XIX gives rise to two pairs of lateral nerves and as such does not differ anatomically, except in size, from a midbody ganglion. Ganglion XX is the last and also the smallest in the ventral chain. Emerging from the posterior third of this ganglion is a single pair of lateral nerves which is directed caudad. From their position and structural composition they should be considered as homologous to the posterior (second) pair of lateral nerves of a typical ganglion. The branches of this nerve extend into somite XXVI.

The anal ganglia, consisting of eight neuromeres, give rise to eight pairs of lateral nerves. The first pair innervates somite XXVII, the remaining seven pairs innervate the sucker. The last three pairs emerge from the posterior

boundary of the anal ganglia and proceed posteriorly as a group. (See Plate No. II, Figs. 2 and 3).

THE SUBEPIDERMAL NERVOUS SYSTEM

The presence in annelids of a nerve net outside the central nervous system has been previously reported by a number of investigators. Among them, Bristol (1899) refers to the "intermuscular nerve ring," Langdon (1905) and Ogawa (1934–39) include in this system the nervous components of the baseepiment. Hess (1925) in referring to the subepidermal nerve plexus, includes the segmental nerve rings and their peripheral components. In Hess's paper (1925) on *Lumbricus* there is presented the functional as well as anatomical relations of this system to the central nervous system. A preliminary description of the subepidermal system of *Haemopis* is given in a previous paper by the author. Miller (1933) Improvements in invertebrate neurological technique, Miller (1944) have made possible the following supplementary statements relative to this phase of the nervous system in *H. marmoratis.*

The intermuscular nerve rings are segmentally located in the second and fifth annulus of each complete somite. Each nerve ring has, as previously reported, a dorso-lateral and ventro-lateral concentration of nerve cell bodies. Lesser aggregations of cell bodies are found more medially than reported earlier. All of the observed cell bodies of this ring are located within the median longitudinal muscle later. The processes of these cells, combine with the processes of the more peripherally located nerve cells on the baseepiment forming a network beneath the circular muscle layer. This network is connected with the central nervous system through peripheral fibers of the paired lateral nerves.

The segmentally arranged intermuscular nerve rings are joined with each other by anterior-posterior connectives. These connectives have been described as single neurons more or less evenly spaced over the dorsal, lateral and ventral surfaces. Further that the cell bodies of these connectives are located some distance from the nerve rings. (Bristol (1899) for *Nephelis lateralis*). Experimental as well as anatomical evidence verifies the existence of such connectives in *Haemopis marmoratis.* In preparations available to me only dorso-lateral and ventro-lateral connectives are resolvable, and they appear to consist of numerous fibers. The location of the cell bodies of these connectives has not as yet been determined. These connective fibers join with those of the nerve ring in the regions of concentration of cell bodies.

The function of the peripheral system is of utmost importance in understanding certain phases of annelid behavior. I have discussed this aspect at some length in previous papers (Miller 1933–36). An accurate knowledge and an adequate understanding of the nervous system is a necessary prerequisite to the analysis of the behavior of any animal.

THE VISCERAL NERVOUS SYSTEM

This division of the nervous system is referred to by most investigators as the sympathetic system. As far as I am able to determine this portion of the nervous system is associated entirely with the visceral organs, and is not metamerically arranged. The only demonstrable connection with the central system is in the region of the esophageal connectives.

The ganglionic masses of the visceral system are confined to annulus eight. They lie medially in relation to the esophageal connectives and are partly obscured by them. They consist of ganglia located on the dorso-lateral surface of the pharynx and joined by a wide circumesophageal band of connectives. Numerous bundles of nerve fibers extend from this visceral nerve center.

From the ganglionic masses there extends anteriorly numerous bundles of fibers into the buccal cavity. Posteriorly similar bundles extend laterally over the surface of the alimentary tract. In addition to the lateral bundles just mentioned there is a dorsal and a ventral bundle extending from the connectives, the fibers of which form a plexus with the branches of the lateral bundles. The muscular surface of the alimentary tract is in this manner covered with an intricate network of fibers. These fibers are however, of two types regarding their origin. Many of them are continuations from the dorsal, ventral and lateral bundles. Others are the extensions of multipolar nerve cells, the cell bodies of which lie within the muscular wall itself. This system is continous over the entire viscera. (Plate No. II, Fig. 1).

The histology of the entire nervous system of *Haemopis marmoratis* will be presented by the author in the very near future.

Summary

1. This study is concerned with a single species of leech, *Haemopis marmoratis*, (Say).
2. Silver nitrate and gold chloride impregnations provide the basis for nerve differentiation.
3. The illustrations are tracings of projected sections or reconstructions from serial sections.
4. The gross nervous system is composed of four divisions; namely, (1) central, (2) peripheral, (3) subepidermal, and (4) visceral
5. The leech is divided into three regions; namely, (1) head, (2) body and (3) anal.
6. The central nervous system consists of an anterior cephalization contained in the head region, a series of segmentally arranged ganglia connected by the ventral nerve cord in the body region, and a caudalization found in the anal region.
7. The anterior cephalization represents six neuromeres, and is contained within somites V and VI.
8. Excluding the subesophageal and anal ganglia there are twenty ganglia in the ventral chain. The first eighteen of which are within the limits established for the body region, the remaining two ganglia are in the anal region.
9. The anal or caudal ganglia is composed of eight neuromeres, and is contained within somites XXV and XXVI.
10. The adult body of *H. marmoratis* is divisible into thirty-four segments. Thirty-four ganglia are resolvable and distributed as just indicated.
11. The ganglia of the ventral chain are joined by a pair of nerve trunks extending from the subesophageal ganglia to the anal ganglia. This portion of the central system is contained within the ventral blood sinus.
12. In each ganglion the nerve cell bodies are contained, for the most part, within six primary capsules, two are median ventral, four are dorso-lateral.
13. Extra-capsular nerve cell bodies are found in the central nervous system, within the ventral nerve cord, within the plexiform substance of the ganglia, and within the ganglia but outside the capsule.
14. Six pairs of lateral nerves arise from the anterior cephalization consisting of the brain, circumesophageal connectives and subesophageal ganglia.
15. Extending laterally and in a horizontal plane are two pairs of lateral nerves emanating from each body region ganglion.
16. The anterior pair of nerves is formed by the union of a dorsal and ventral root.
17. From the posterior third of ganglion XX there emerges a single pair of lateral nerves.
18. Emanating from the anal ganglia are eight pairs of lateral nerves. The three posterior pairs emerge as a group and are directed caudad.

19. Intermuscular nerve rings are segmentally located in the second and fifth annulus of each complete somite. With each nerve ring is associated a dorso-lateral and ventro-lateral aggregation of nerve cell bodies.
20. The peripheral nerve net is situated beneath the circular muscle layer, and is connected with the central system through peripheral fibers of the paired lateral nerves.
21. The visceral (sympathetic) division of the nervous system is associated entirely with the visceral organs. There is no indication of segmentation and its only connection with the central system is in the esophageal region.
22. The ganglionic masses of the visceral system are confined to annulus eight. Bundles of fibers emanating from the visceral ganglia extend anteriorly into the buccal cavity and posteriorly over the surface of the viscera.
23. Posterior visceral fibers, supplemented by processes from nerve cells in the viscera form a plexus over the surface of the organs.

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New Crops for the New World

This book is of paramount importance to those who are interested in tropical agriculture and particularly in the new phases that have developed in Latin America. Dr. Wilson Popenoe has contributed two of the chapters, "The undeveloped field of tropical fruits" and "Cinchona, the fever tree." From his years of experience as plant explorer, research director for the United Fruit Company and now Director de la Escuela Agricola Panamericana, Popenhoe is known far beyond his special field of interest. Edgar Anderson, Albert O. Rhoad, Miriam L. Bomhard, Walter N. Bangham, E. C. Higbee, C. P. Clausen, Arthur Bevan, George E. Adames, Atherton Lee, A. T. Erwin, B. Y. Morrison, P. Honig, and V. C. Dunlap complete the list of contributors to make a book that contains too much carefully worked over data entertainingly presented to fit into a brief review. At no time before have so many biologically trained persons all directed their effort toward the development of western hemisphere crops. The reader can gain an understanding of what the world may expect from teamed effort.—*A. E. Waller.*

New Crops for the New World. Edited by Charles Morrow Wilson. The Macmillan Company, New York, 1945, pp. 295. $3.50.

ON THE STRUCTURE AND MECHANICS OF THE PROTOZOAN FLAGELLUM[1]

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The flagellum is an organelle of exceedingly wide distribution among both animals and plants. Among the Protozoa, it occurs not only in all of the Mastigophora, but also in many Sarcodina and Sporozoa during part of their life cycle. The swarm spores and gametes of certain algae and fungi possess flagella, as do the sperm cells of bryophytes, pteridophytes, and cycads. The tail of the typical animal spermatozoon is probably nothing more than a flagellum. The cilia of the ciliate Protozoa and of metazoan ciliated epithelium in all probability represent modified flagella. There is reason to believe that the bacterial flagellum is perhaps the simplest and most primitive manifestation of this organelle. In spite of the apparent diversity of form and function represented in these numerous examples, it seems highly probable that the organization and mode of functioning are fundamentally similar in all.

During the past century numerous investigators have studied the structure and mode of action of flagella, and their conclusions have varied widely. Certain facts have been established, but many points have remained open to question. It has been evident for some time that new techniques would be necessary for the settlement of such questions. Today the electron microscope, with resolution and accompanying magnification far beyond the limits of the ordinary compound microscope, provides such a new technique for the study of minute structures.

Having access to an electron microscope and to pure clone cultures of several flagellate Protozoa, I undertook an intensive study of flagellar structure, the major results of which are embodied in this paper. Flagellar action and flagellate locomotion I investigated by direct observation with the aid of a special technique, by the construction of working models, and by actual underwater swimming experiments.

The work was done at the suggestion and under the supervision and encouragement of Professor W. J. Kostir, to whom I am especially indebted. The electron microscope employed was one constructed by Professor A. F. Prebus, of The Ohio State University, and operated by him and his assistant, Mr. John Dankworth, to both of whom I here express my appreciation for invaluable assistance.

Review of Previous Work on the Subject

STRUCTURE OF THE FLAGELLUM

Until the 1880's or later, the flagellum was generally considered simply an elongate, homogeneous fiber, bearing no appendages, and characterized by weak staining (Bütschli, 1883–7; Klebs, 1892; Dangeard, 1901 b). The flagella were usually depicted as tapering to a point, but Bütschli considered them commonly of equal diameter throughout their entire length, or tapering only slightly at the end.

In opposition to such views appeared the papers of Kunstler (1882, 1889), Loeffler (1889, 1890), and Fischer (1894, 1895). The former described (Kunstler, 1889, p. 408, translation) " . . . a dark axial line resembling a slit or canal, partic-

[1]From a dissertation submitted to the Graduate School of The Ohio State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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ularly when the filaments observed are well extended horizontally; in these cases one may often distinguish delicate transverse septa, dividing the axial cleft into rather short sections." (Fig. 1 *a*). The dark sections he considered to represent vacuoles which are separated from one another by septa of the transparent ground mass which surrounds them. He also described a cortical layer or sheath (Fig. 1 *b*, *c*) which was often separated from the ground substance and its enclosed slit.

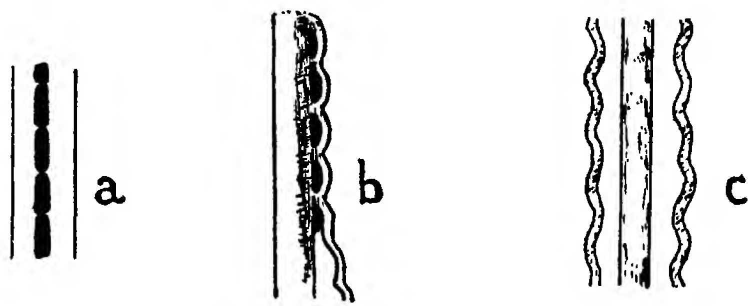

FIG. 1. a. "*Oxyrrhis marina*. Portion of flagellum showing the central fissure sufficiently enlarged to be quite clearly visible, and appearing like a slit or axial groove divided into a series of hollows by delicate transverse septa." b. *Oxyrrhis marina*. "The same flagellum (as *c*) seen at a place where the outer layer is detached only on one side, and only incompletely, in such a way as to form a rather regular sort of corrugation. The cleft which separates it from the internal axis becomes increasingly narrower, and, farther along, even disappears." c. "*Oxyrrhis marina*. Portion of flagellum greatly enlarged and treated with chromic hematoxylin. The undulated outer coat is completely detached from the axial substance." (Redrawn from Kunstler, 1889, Plate XIX.)

To the presence of this enveloping membrane he attributed the weak stainability of the flagellum. The axial substance he considered the more contractile portion. Kunstler also first described an interesting external structure in the flagella of *Oxyrrhis* and *Cryptomonas:* " . . . the attenuated extremity often seems prolonged in a pale filament, thinner than the flagellum and of a different appearance (Fig. 2). The limits of the flagellum proper are distinguished clearly; suddenly, at its tip,

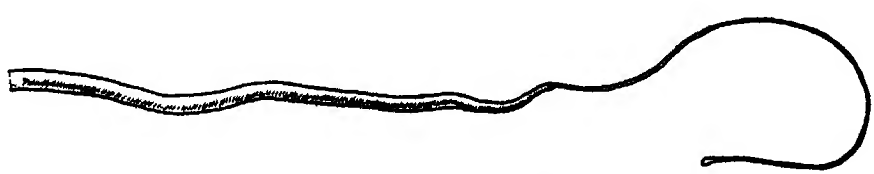

FIG. 2. "*Oxyrrhis marina*. Theoretical figure representing certain flagella. One sees at the end of the true flagellum the pale filament which may be observed in many cases. The same may be seen in *Cryptomonas ovata*." (From Kunstler, 1889, Plate XX.)

the diameter and appearance change; there begins a transparent filament, hardly visible, very slender, sometimes ending in a slight swelling."

Loeffler (1889) independently described this last-mentioned structure, employing a new technique he was using for bacterial flagella. He suggested that the thick basal part might be a sheath, from which extends the delicate protoplasmic fiber in the manner of a pseudopod, slightly swollen terminally. The apical swelling, he postulated, might function as a tactile organ. Loeffler also discovered on the

flagellum of a monoflagellate (perhaps *Oikomonas*) two dense rows of extremely delicate hairs, projecting almost at right angles to the axis of the flagellum, one along each side. (See Fig. 3). He did not investigate the possibility that in life the hairs actually might cover the filament instead of being arranged in two rows, and in drying be flattened down laterally, producing the impression of two rows of hairs. At any rate, he had described and figured photomicrographs of two previously unknown appendages, and outlined his method in detail.

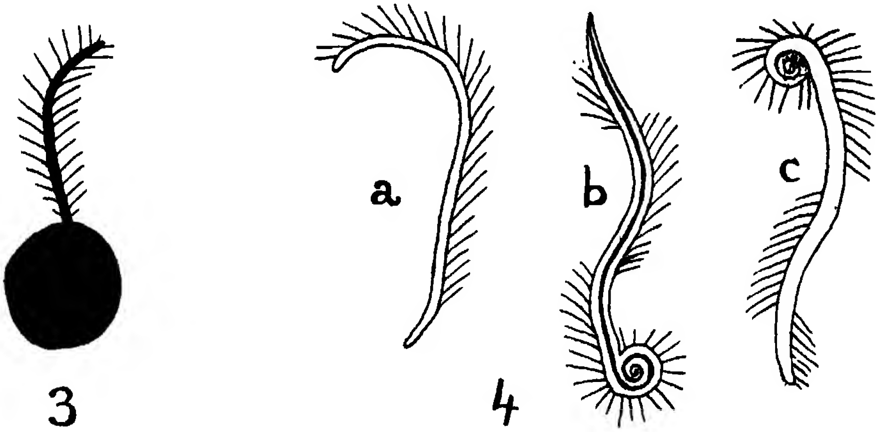

FIG. 3. *Monas* sp. ? The first published figure of a flimmer-flagellum, from a mordant-stain preparation designed for bacterial flagella. (Redrawn from Loeffler, 1889, Plate II.)

FIG. 4. *Euglena viridis*. a. "Cast-off flagellum . . . still completely stretched out; untwisted, with the hairs on one side . . ." b. "A cast-off flimmer-flagellum rolling up, partially swollen and therefore with an apparent axial fiber." c. "A cast-off, rolling-up flagellum which had previously become uniformly swollen and consequently shows no such apparent structure" (as Fig. 4 *b*). From preparations of undiluted culture dried upon cover glasses in about one-half hour, and treated with a modification of Loeffler's mordant-stain technique. (Redrawn from Fischer, 1894, Plate XI.)

Fischer (1894), using a modification of Loeffler's technique, made a careful study of the flagella of ***Euglena viridis***, ***Monas guttula***, and species of ***Bodo***, ***Chlorogonium***, and ***Polytoma***. He confirmed Loeffler's findings and discovered that in ***Euglena*** the flagellum bears but a single row of hairs (Fig. 4), while that of ***Monas*** has two opposite rows. He termed these flagella Flimmergeisseln, or ciliated flagella. Since "flimmer" appears to be a convenient word for the structures, and does not carry any obvious implications in the English language, I shall hereafter employ the term "flimmer-flagellum" in reference to any flagellum bearing hair-like projections along one, two, or all sides.

Whip-flagella, or Peitschengeisseln, Fischer found in ***Bodo***, ***Chlorogonium***, and ***Polytoma***, and described as follows (p. 230, translation): "The whip-flagellum consists of a thick homogeneous stalk, previously thought to be the entire flagellum (the only part visible in unstained specimens) and, arising from its tip, a very delicate whip-thread 2–3 times as long as the stalk. This thread is slung about like a coach-whip by the strokes of the basal stalk."

Fischer observed in ***Euglena*** what he concluded to be an artifact arising from incomplete swelling: ". . . the central, not yet swollen part of the flagellum appears as a denser, more strongly stained axial fiber, while the outer, swollen part, seems a less dense, more weakly stained ground substance." (See Fig. 4 *b*). Further, "In ***Polytoma*** and ***Bodo***, a relatively commonly seen granular structure of the basal part of the whip is likewise only a result of the technique. This flagellar structure,

which agrees with that described by Kunstler, is to be regarded in this light" (i. e., as an artifact). (For further discussion of the granular appearance, see Gelei, 1926.)

Fischer studied in detail the processes of flagellar disintegration, whereby he made his observations on the artificial nature of the granular or alveolar appearance of certain flagella. He figured in detail many examples of all the above-mentioned types, and discussed each matter thoroughly. In spite of the fact that he could demonstrate no natural inner structure in either whip- or flimmer-flagellum, he stated (p. 204): " . . . yet there is no doubt that the apparently homogeneous fiber must possess a very fine structure made up of definitely arranged particles (micelles), toward which point the twisting of the flagellum, its rolling up, and the arrangement of the flimmer-hairs."

Regarding the arrangement of the flimmer, Fischer assumed that they must beat in unison, since, on any given flagellum, all the flimmer project in the same direction.

For years flimmer-flagella were generally considered artifacts, perhaps the result of a final wriggle and smear, or of chemical action (Plenge, 1898; Dangeard, 1901b; Bütschli, 1902; Schuberg, 1905; Korschikov, 1923; Günther, 1928). On

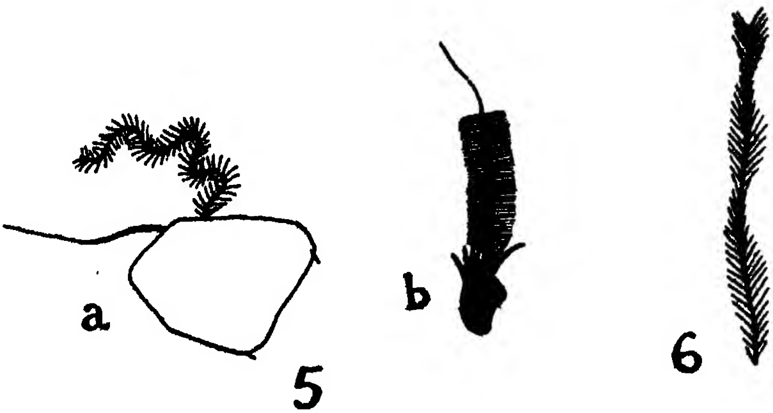

FIG. 5. a. "*Synura uvella* Ehrenb. A cell from the colony with flimmer- and whip-flagella." b. "*Salpingoeca* sp." (Redrawn from Petersen, 1929.)

FIG. 6. Schematic flimmer-flagellum showing appearance which would be expected to occur in a twisted flagellum if the flimmer existed in two lateral rows, rather than all over the surface of the flagellum. This sort of appearance has not been observed in specimens, although many of the observed flagella have probably been twisted. (From discussion and diagram of Vlk, 1938.)

the other hand, most of these workers confirmed the existence of whip-flagella, and in many cases observed such structures in living specimens. During the latter part of the period covered by the above references, several investigators were, however, confirming the reports of Fischer and Loeffler. Petersen (1918) demonstrated the two flagella of *Synura uvella* to be of different types (Fig. 5*a*): " . . . the one of whiplike form, the other a pinnate flagellum showing two opposite rows of little secondary filaments, and resembling a feather; it is to be presumed, however, that these [filaments] extend from all sides of the primary filament." (Translation from summary in French.) Petersen also found flimmer-flagella in *Uroglena* and *Dinobryon*. In a later paper (1929) he expanded his observations to a large number of forms, some possessing only whip-flagella, some only flimmer-flagella, and some having one of each. He also described a combination whip-flimmer-flagellum in Craspedomonads. (Fig. 5 *b*). The distribution among the Protozoa of consistent flagellar types fits well into the accepted scheme of classification.

Mainx (1928), though failing to demonstrate flimmer-flagella in several species reported to possess them, confirmed their presence in *Euglena viridis* and figured excellent photomicrographs of the flimmer-flagellum of *Phacus pleuronectes*. His most exacting attempts to observe flimmer on the living flagellum failed. In consideration of their extreme regularity along one side of the flagellum, their presence with or without fixation, etc., he concluded that they could hardly be artifacts. He considered them, however, not motile, as Fischer had assumed, but rather simply as devices serving to increase the flagellar surface.

Petrova (1931) employed flagellar types in the solution of a taxonomic problem.

Deflandre (1934), using a very different method of preparation, confirmed the presence of whip- and flimmer-flagella in many organisms, and considerably expanded the list of species studied.

Vlk (1931, 1938) has perhaps treated the problem most thoroughly, expanding and organizing the described types, and tabulating his results. For a more thorough treatment of this phase of flagellar structure, the reader is referred particularly to Vlk, 1938, or to Deflandre, 1934. Vlk even succeeded in observing flimmer (in two distinct rows) on the flagellum of active, living specimens of

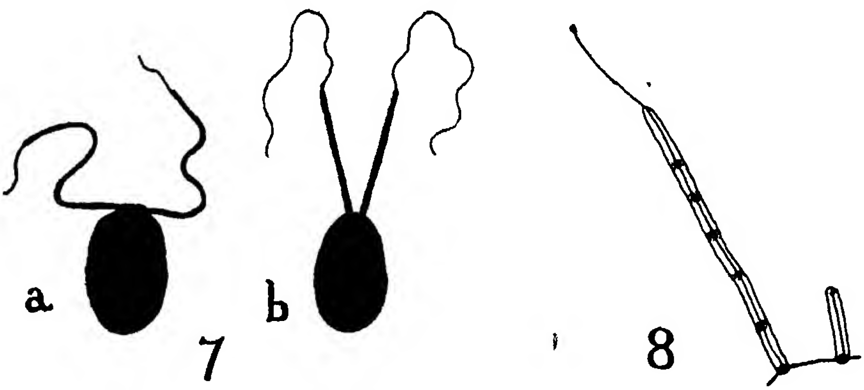

FIG. 7. a. Whip-flagella of *Chlamydomonas moewusii*. b. Whip-flagella of *Chlamydomonas sestinensis*. (Redrawn from Gerloff, 1940, to show variations in length of whip.)

FIG. 8. *Cyclidium glaucoma*. Silver preparation. Greatly enlarged cilium showing the axial fiber extending from the basal granule through and beyond the "contractile" sheath, and ending in an enlargement. The dark areas in the sheath are irregularly spaced and even lacking in some of the cilia nearby. A silver line connects adjacent basal granules. (Redrawn from part of Text Figure 34, Klein, 1929.)

Mallomonas acaroides, a species having an unusually large flagellum. These flimmer are described as having a length about 6 times the diameter of the flagellum proper. He was able to demonstrate these living flimmer-flagella to members of the institute staff, including Professor A. Pascher.

Unfortunately, Kudo (1939), in his brief treatment of the flimmer-flagellum, gave all credit to Vlk but misrepresented Vlk's diagram of a two-row flimmer-flagellum (Fig. 6). The error is certainly unintentional, but misleading. This diagram, which Kudo used to illustrate a two-rowed flimmer-flagellum, was originally intended by Vlk (1938, p. 486) to represent a situation which *should* occur in twisting if the flagellum actually bears two distinct flimmer rows. But such a situation had never been observed. Instead, the flimmer of these forms usually appear somewhat as in Fig. 3 or Fig. 5 *a*. In other words, Vlk used it as a probable indication that the flimmer, in most organisms at least, are distributed on the surface of the flagellum like the hairs on a dog's tail, and not just in two lateral rows.

Recognition of the whip-flagella has been rather general, and they seem almost universally accepted today. Gerloff (1940) figures the whip-flagella in many species of *Chlamydomonas*. A considerable variation in relative length of lash and stalk may be noted (Fig. 7). Many authors (e. g. Awerinzew, 1907; Minchin, 1922) consider the lash or end-piece as a portion of an axial fiber extending beyond the enveloping sheath of protoplasm and membrane. Cilia are now commonly considered to have a similar structure (Klein, 1929). Klein seems to agree with Loeffler's hypothesis that the terminal swelling of the lash (Fig. 8) may have a sensory function.

Figure 8 (or 10 *a*) will also serve for a discussion of the generally accepted concept of the internal structure of a flagellum. Most textbooks and articles on the subject agree to the presence of an axial fiber surrounded by a protoplasmic

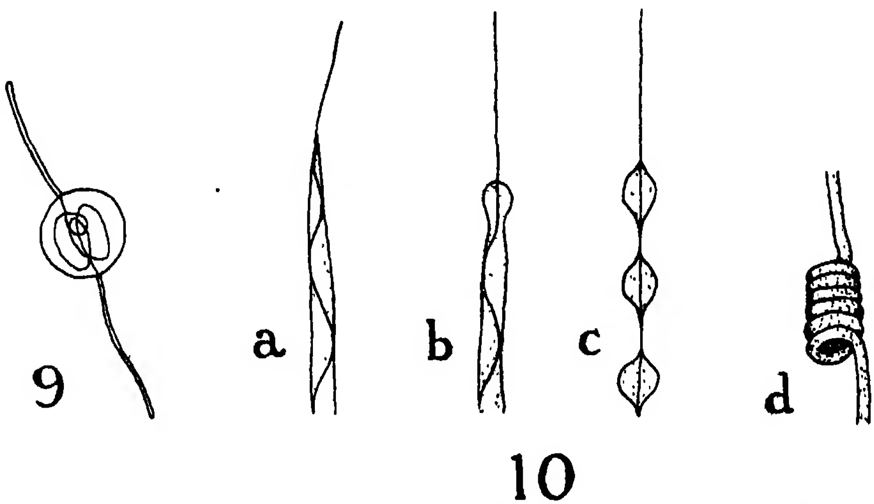

FIG. 9. Flagellum of *Peranema* in which the axial fiber and outer membrane are intact, although part of the intermediate substance has swollen and formed a knot or coil of the axial fiber. (Redrawn digrammatically from Korschikov, 1923, Fig. 1.)

FIG. 10. a-c. Flagellum of *Chilomonas paramecium* undergoing disintegration (half-schematic). The protoplasmic portion flows together into droplets, exposing the axial fiber and allowing it to straighten. d. *Ceratium tripos.* Part of contracted longitudinal flagellum. (Redrawn from Awerinzew, 1907.)

sheath. Beyond that there is much less agreement. A few consider the axial core as the major contractile or vibratile portion, the sheath serving as a supporting structure (Rosskin, 1922; Calkins, 1933). The vast majority think differently. (Bütschli, 1902; Schuberg, 1905; Awerinzew, 1907; Goldschmidt, 1907; Williams, 1907; Erhard, 1910; Hamburger, 1911; Minchin, 1922; Korschikov, 1923; Doflein, 1929; Klein, 1929; Kudo, 1939; Hyman, 1940).

The flagellum (or its axoneme) usually arises from a basal granule (blepharoplast), apparently essential to the continued function of the organelle. In certain forms the flagellum has two roots and basal granules (e. g. *Euglena;* Wager, 1899; Hall and Jahn, 1929). For information on other modes of attachment, see Prowazek, 1903; Goldschmidt, 1907; Schouteden, 1907.

Regarding the interrelationships among axoneme, surrounding plasm, and outer membrane, there are interesting reports, based upon studies of disintegrating flagella, which throw light upon the subject. Fischer (1894) made extensive

observations on the coiling or rolling-up of flagella, noting that the process might begin at either end of the flagellum or at any point in between. Korschikov (1923) confirms Fischer's description of flagellar "aggregation" (Figs. 4 *b*, *c*; Fig. 9), summarizing his observations as follows (translation from German summary): "The axial fiber and the outer membrane are the most resistant structural components of the flagellum. In the 'aggregation' of the flagellum, the intermediate substance is first destroyed. In the corresponding region the membrane becomes swollen. In the course of this process, the axial fiber is drawn into the swelling and forms there a ball or coil (Fig. 9). Afterward, however, when this blister of the flagellar membrane is destroyed, the axial fiber is freed and stretches again in length."

Awerinzew (1907) and Hamburger (1911), describing flagella undergoing destruction, state that the "protoplasmic" portion of the flagellum rounds into globules which proceed to flow or withdraw toward the base of the flagellum, either leaving the axoneme exposed and straightened out (Awerinzew) or telescoping it (Hamburger). (See Fig. 10.) All of these facts tend to indicate an elastic, upporting axoneme.

Úlehla figures, but barely mentions, an interesting flagellar structure (Fig. 15), reminiscent of Kunstler's diagrams, but seen in living flagella.

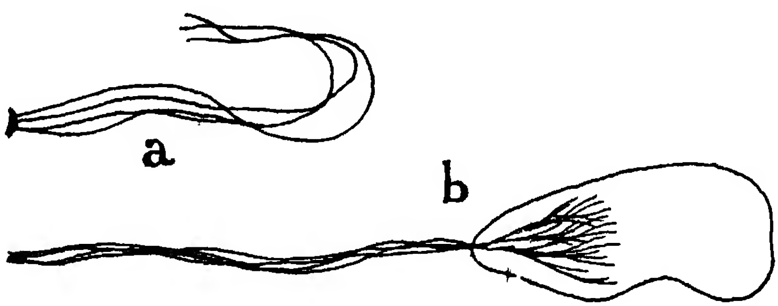

FIG. 11. a. "The uncoiled fibrils of the flagellum of Euglena." b. "Euglena with the fibrils of the flagellum branching out into a system of rootlets in the protoplasm of the body." "This structure is demonstrated with ease by subjecting a flagellum to slight pressure." (Drawn from Dellinger, Figs. 1, 3.)

Roskin (1922, 1923) postulates and Korschikov (1923) asserts that the axial fiber consists of a great number of thin fibrils. Koltzoff (1903) stated that in certain pteropods the cilium "consists of several fibers which are encased in a common fluid plasma layer . . . the inner fibers running to the basal body . . ." Schmitt, Hall, and Jakus (1943) figure cilia (*Frontonia*) and flagella (*Trichonympha*) frayed into 9–11 fibrils.

Dellinger (1909), who figures fibrils in both cilia and flagella (Fig. 11), states: " . . . the flagella of Euglena, Chilomonas and Spirillum are composed of four spiral filaments." He also depicts the axial filament in the pseudopod (axopod) of *Actinosphaerium* (Heliozoa) as fibrillar. A similar structure is described in the heliozoan axopod by Rosskin (1925). For discussions of the possible homology between such pseudopods and flagella see Minchin (1922), Goldschmidt (1907).

The flagella of many bacteria entwine in a tuft and function as a unit, in some cases even becoming encased with a glutinous mass which keeps them bound together (Reichert, 1909; Úlehla, 1911; Metzner, 1920; Pijper, 1941; Hutchinson and McCracken, 1943). This situation is perhaps analogous to that occurring in cirri or in the "cilia" studied by Gray (1922) and Carter (1924), in which a number of units capable of beating individually are united into a single organelle.

Sperm tails display a fibrillar axis and an enclosing sheath, and have been more exhaustively studied than flagella. Furthermore, they are probably homologous to the protozoan flagellum, although the details of the homology are not yet settled (Dangeard, 1901a; Alexeieff, 1924; Grassé, 1926; Duboscq and Grassé, 1933). Subsequent to the work of several investigators, Ballowitz stated in 1890 that many types of sperm tails frayed into 2–4 subfibrils. In his paper of 1908, he figures tails fraying into as many as 18 subfibrils. Koltzoff (1909) produces interesting figures of sperm tails, including such as Fig. 12, showing a sheath of helically wound gel fibrils. Recently the electron microscope has made possible more minute studies. Several articles (Baylor, Nalbandov, and Clark, 1943; Harvey and Anderson, 1943; Schmitt, Hall, and Jakus, 1943; Schmitt, 1944) figure micrographs of sperm tails showing, in frayed parts, 9–12 fibrils (Fig. 13). According to


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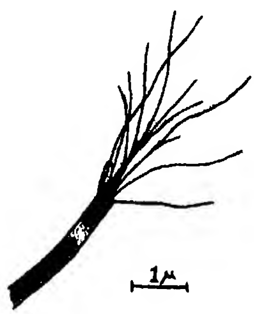

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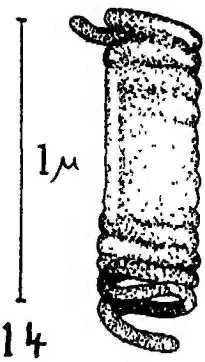

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FIG. 12. Flagellum (tail) of *Planorbis* sperm, showing outer helix of gel fibers. (Redrawn from Koltzoff, 1909, Fig. 13.)

FIG. 13. "Frayed tail of bull sperm showing subfibrils."

FIG. 14. "Portion of sheath from human sperm tail fragmented ultrasonically, showing helical structure." (Redrawn from electron micrographs; Schmitt, 1944, Figs. 1, 2.)

FIG. 15. "*Gonium pectorale*. A portion of a momentarily resting flagellum, showing the structure of the flagellum. The helical lines proceed . . . uninterruptedly to the tip. (Schematic)." (Redrawn from Ulehla, 1911, Fig. 55.)

Schmitt, these fibrils are smooth, parallel, 300–500 A wide, and run the full length of the tail. Occasionally even finer subfibrils are seen. "In mammalian sperm tails the bundle of fibrils is surrounded by a sheath, the major component of which is a closely wrapped helical fibril, having a thickness also in the range of 300–500 A (Fig. 14). When the tails are fragmented by ultrasonic radiation, portions of this helix can be seen, appearing like miniature solenoids." (Schmitt, 1944, p. 36.)

MECHANICS OF THE FLAGELLUM

In the past, little actual correlation has been made between structure and function in flagella. Many authors have recorded types of flagellar movement and general movement, but relatively few have attempted to analyze the forces or mechanisms involved. First, let us enumerate the types of movements described. Ulehla (1911, pp. 727–728) classifies them as follows:

(1) Monad type. Flagellum long, cylindrical, flexible; beats forward in loops (spirals) grading into flattened waves (i. e., undulations; a given point on the flagellum follows an elliptical path).

(2) Chrysomonad type. Similar to above, but with shorter and stiffer flagellum.

(3) ***Euglena*** type. Long, twisted, ribbon-like flagellum; beats laterally in loop-shaped waves.

(4) ***Bodo*** type. (Trailing) flagellum with long end-piece, rather stiff; beats in flattened waves.

(5) ***Clostridium*** (a bacterium) type. Flagellum long, spiral, rather stiff; slow waves from base to tip.

(6) Chlorophycean type.

a. Swarmer type. Flagellum short, cylindrical, rather strong, with the basal part more flexible; functions as an oar (in sculling?), swinging around as if contracting as a unit.

b. ***Pandorina*** type. Flagellum longer, more flexible, often somewhat flattened; beats with a spiral lateral stroke.

Úlehla hardly considered the paddle-stroke as such, though this type of movement is described by many, being reported in flagella by Plehn (1904), Rosenbusch (1908), Doflein (1916), Kofoid and Swezy (1920, 1923), Krijgsman (1925), Nigrelli (1929), Kirby (1943); in cilia by Gray (1922) and Carter (1924), among others. Such a lash-movement is mentioned also by Pütter (1903), Goldschmidt (1907), Schindera (1922), and Grassé (1926). In some such cases, it evidently occurs in flagella which ordinarily undulate. In all of these cases, the flagella concerned were located anteriorly.

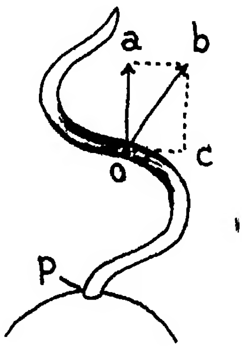

FIG. 16. See text for explanation.

The second major type of movement executed consists of undulations, usually occurring in two planes (i. e., a spiral). Reports of this type may be found in Bütschli (1887), Kunstler (1889), Goldschmidt (1907), Laveran and Mesnil (1907), Friedrich (1909), Reichert (1909), Bancroft (1913), Kofoid and Swezy (1919), Schindera (1922), Grassé (1926), Entz (1928), Petersen (1929), Lowndes (1936, 1941, 1943, 1944, 1945).

The third type, not listed above, is simple conical gyration, reported by Keysselitz (1906), Metzner (1920), and Entz (1928), and by McDonald (1922), in cilia.

Primarily because of Krijgsman's detailed paper, which was based on studies of ***Monas*** sp. under darkfield, most textbooks today emphasize the paddle-stroke. It presents a clear-cut, diagrammatic, relatively simple-looking movement, familiar in our own swimming stroke and similar to that commonly depicted for cilia. The filament is held rigid during the effective stroke, but is flexible during the recovery stroke.

The concept of progression by a spiral turning of the flagellum has led a painful existence because of Bütschli's analysis of the situation as he saw it (Bütschli, 1887, p. 857 et seq.). Delage and Hérouard (1896, pp. 306–307) treat his explanation thus

(translation): "Suppose that the flagellum assumes the form of an elongate helix (as indicated in Fig. 16), and that this helix begins to turn clockwise (as seen from the base). At any point such as *o* the pressure on the water would create a force *ob* perpendicular to the flagellum, which could be resolved into two others, the vertical one *oa* determining its rotation about its axis. It is to be noted that this rotation is in the opposite direction to that of the flagellum. If the helix turns in the reverse direction, the animal will go backwards. In the case of a helix wound to the left, there would be likewise progression forward for a certain direction of rotation and backward for the opposite direction. . . . All that is very well, but Bütschli does not note that the movement he describes supposes an agency met in our mechanical instruments, but never among living beings. In order that the body and the flagellum might turn indefinitely in opposite directions about the point *p*, it would be necessary that the mode of union between them be that of a pin stuck through a card, capable of turning freely in its hole, its union with the card assured by the head which could not go through the hole." But this leaves Delage and Hérouard with the problem of explaining matters. They do so by going into great mathematical detail concerning the possibility of a forward component produced by conical gyration, concluding this to be impossible by direct action. However, by its indirect action, i. e., by the rotation produced in the body, they think to have found the answer; namely, that since the flagellum is firmly attached to the body it must rotate with the body, and being held in a corkscrew shape, will thus screw the body and flagellum through the water.

Reichert (1909) noted the forced aspect of this scheme and pointed out that, in his experience, the facts argued against such a mechanism. Further, he states (translation): "The necessity for their relatively cumbersome explanation of flagellar movement appears to have been a result of a misconception of Butschli's idea. For Butschli postulates that an opposing rotation of body and flagellum is not feasible in his view that the lines of contraction move about the flagellum. If the lines of contraction on the flagellar surface circle to the right, the body will turn to the left, and so will the flagellum, about its axis. . . . It is only necessary that the lines of contraction move correspondingly faster about the flagellum, so that its turning with the body is equalized or offset. Then the same effect would be achieved as if this turning of the flagellum did not occur at all."

Delage and Hérouard are not the only ones to misinterpret Butschli's idea.

Reichert explains it, and the physics involved, quite clearly. Then, in his summary he states: "Reversal of movement is accomplished quickly by polar-flagellated bacteria, for they simply reverse the flagellar rotation (as Reichert and Bütschli postulate that they should), or by bipolar-flagellated bacteria, whose flagella take turns (those at the other end begin beating). In peritrichous bacteria, on the other hand, reversal occurs slowly. Movement must first cease for a moment, and the flagella assume an opposite orientation to the body." But he is inconsistent, for he also states: "*a.* The flagella (in bacteria) are always wound in a right spiral (clockwise) and rotate always to the right (as seen from the rear), i. e., the screw-like lines of contraction wind around the flagella to the right. *b.* The body always rotates to the left. *c.* The flagella are usually directed backward during locomotion. In the spirilla this occurs too, whether the flagellum arises at the anterior or posterior pole." If they "*always*" rotate in one direction, how can they "*simply reverse*" this rotation? Further, if the flagellum is directed backward during locomotion, whether the flagellum be at either end of the body, does this not indicate that the flagellum is assuming a different orientation, rather than that it is merely rotating to the right or to the left? For, if it simply reversed its direction of rotation in order to back up, it would then pull the body instead of pushing it, and would not be directed backward. The error doubtless lies in the assumption that the organism moves backward by simply reversing the flagellar rotation. Indeed, the theory itself seems disputed by these facts.

Gray (1928, p. 35) gives a fine explanation of the mechanics involved in undulating flagella, the gist of it being that there is a series of waves passing along the flagellum in the same direction, requiring no recovery stroke. The propulsive power " . . . is equivalent to that which would be produced by projecting along the length of the flagellum a series of 'humps' of the same form as the waves, the velocity of the humps being made equal to the velocity of movement of each wave. If the waves pass from the base of the flagellum to its tip, the organism is driven forward in front of the flagellum; if the waves pass from the tip to the base the organism is drawn forward with the flagellum in front. If the waves pass along the flagellum in one plane there will be no force tending to rotate the animal on its axis: if, however, the waves pass round the flagellum as well as along it the organism will rotate." This is well and good, but it fails to fit a couple of facts; namely, that most flagellates move flagellum-foremost, and that the waves of transmission along the flagellum have only been demonstrated to progress from the base toward the tip (Lowndes, 1936, 1941 a and b, 1943, 1944 a and b, 1945 a and b).

To date, Lowndes has made the most complete and accurate analysis of the situation in a number of flagellates. His conclusions are based upon observed facts and specific data, backed up by high-speed cinema photomicrography (for techniques, see Lowndes, 1935, 1944 a). Too much of previous explanations was based upon pure speculation and rationalization. Lowndes (1941 b) has demonstrated that the flagellum ordinarily *pushes* the organism, even though situated at the anterior end, by being directed backward. In this connection it is interesting to consult Úlehla's figures, many of which indicate the same. This appears true even for ***Peranema***, the organism classically cited as having a "tractellum," or flagellum which pulls the organism forward, presumably by a wave starting at the tip. Lowndes shows that, in all cases studied, the wave invariably progresses from base to tip. This fact is an upsetting one to most of the previous theories. Among other workers reporting this type of action are Kunstler (1889), Friedrich (1909), Úlehla (1911), Bancroft (1913), and Schindera (1922). Of these, Úlehla and Bancroft give accounts almost precisely like that of Lowndes concerning the locomotion of ***Euglena viridis***.

In his later papers, Lowndes elaborates a new concept, previously mentioned by him, but misunderstood by such workers as Barker (1943). In the summary of one of these papers (Lowndes, 1944 a), he states it as follows:

"1. The primary function of the flagellum in a monoflagellate organism is to produce both rotation and gyration of the organism about a certain axis which constitutes the main direction in which the organism is swimming.

"2. The mechanical principle by which the organism is propelled is simply that of the inclined plane which is caused to rotate. In other words it is that of the screw or propeller.

"3. Since the disturbances or waves pass down the flagellum in the form of a spiral they produce two distinct components. It is the resultant of these two components which causes the tip of the organism both to rotate and gyrate.

"4. So long as this rotation and gyration is maintained it will supply the necessary force for the propulsion of the organism.

"5. The flagellum itself may or may not produce a forward component. If it is more or less swung out at right angles, as in ***Menoidium***, it will produce no forward component but if it is swung back, as in ***Euglena***, it will do so."

Hence, it is the ***rotation and gyration of the body*** of the organism which is considered to produce the major component of force. Others have observed, naturally, that in organisms bearing obvious helical external structures, rotation of the body would produce a component of force. For instance, Günther (1928) correlated the speed of several species of ***Euglena*** with spiral ridges on the periplast and flagellar length. Thus, of two species having flagella of approximately the same length, one having strong spiral ridges progresses at about three times the relative

speed of another having very insignificant ridges. But no one previous to Lowndes, so far as I know, had suggested the possibility that the *gyration of the body itself* might produce locomotion.

Propulsion by simple conical gyration is what Delage and Hérouard thought they had proved, by mathematics, to be impossible. Metzner (1920) showed this to be erroneous, both in theory and in practice. By means of experiments on wires rotating in water, he demonstrated that a simple conical gyration produces a pulling force which reaches maximum at an angle of 20–23 degrees from the axis of rotation. He even went so far as to state (translation): "Among flagellates, the simple conical gyration predominates; the organism 'sucks' itself along through the water by means of the flagellum." It should be noted that he considered only gyration of the flagellum, not gyration of the body. Such conical gyration of the flagellum is reported by Keysselitz (1906) and Petersen (1929). It is also described by Lowndes (1944 b), who performed experiments similar to those of Metzner. However, Lowndes contends that this mode of locomotion is incompatible with high speed, as the flagellum could not be maintained in such a forwardly-directed position. In rapidly moving organisms, the flagella must beat laterally to the rear.

In this same paper, and in his most recent one (1945 b), Lowndes renders untenable a number of misconceptions which arose long ago through misinterpretation of the original data, and have grown or continued from textbook to textbook. One such item regards diagrams of *Monas* swimming, taken from Krijgsman (1925). I shall not discuss these errors here. As Lowndes points out, Krijgsman's observations were excellent records of the situation he was studying, *but* that situation was not representative of the free swimming of the organism. When the animal is freely swimming, the mechanism is quite different from the paddle-stroke observed by Krijgsman, being similar to that described by Lowndes for *Euglena*, and the rate of progression is about ten times as rapid as that given by Krijgsman. Locomotion is primarily brought about by the rotation and gyration of the body of the organism. (See also Lowndes, 1945 a.)

As for the question of the precise nature of what goes on within the flagellum—it remains a question. For years, writers were occupied with a controversy as to whether the flagellum was an active unit or simply an appendage like a whip, manipulated from the base or cell body. The latter concept was eventually discarded as such, but lingers in part in the question whether or not the flagellum can execute any movement after losing connection with the cell. Various workers (e. g. Klebs, 1892; Entz, 1926) have reported the phenomenon; others have flatly asserted such to be impossible (Verworn, 1890; Korschikov, 1923). However, the work of many investigators has indicated that the flagellum is an active unit. Gray (1928) enumerates good reasons for assuming such, and Lowndes (1936, 1941 b, 1945 b) proves it with photographic, quantitative evidence. Granting, then, that the flagellum does possess the ability to move, by what mechanism does it effect this motion?

From the versatility of movements and also " . . . because its movements at times cannot be explained by simple mechanical laws," Krijgsman (1925) concluded that the flagellum " . . . must be of complicated construction." Engelmann (1881) and Ballowitz (1890) assert that movement is associated with fibrillar structure, which, as we have seen, is evidently present. Erhard (1910) and Lowndes (1941 b) regard the transmission of the stimulus as a surface phenomenon, not connected with the axoneme. Such statements are generalities, to be sure, but, if accepted, eliminate such theories as that of Gurwitsch (1904), which postulates a rapid streaming of protoplasm into and out of the flagellum, acting in antagonism to the elasticity of the axoneme. Heidenhain (1911) proposed a "theory of smallest waves" to explain movements: these waves may travel along one side of the filament, they may vary in length and effect, they may vary in extent, they

may vary in path, frequency, and rhythm. They are evidently quite versatile waves. So far as I know, they have been forgotten. Pütter (1903) discussed Engelmann's theory and decided that it required too many spiral fibrils of different pitch and direction. Verworn (1915) stated what he considered the basic principle involved (translation): " . . . a contractile side contracts from the cell body outwards and thereby stretches the opposite side, which latter in the expansion phase, by its elasticity, returns the filament to its rest position. According to the opposing relationship of the contractile to the passively stretched substance, there results a beat in one plane or in a complicated form." This does epitomize the principle employed by most of the theories. For a discussion of the theories, see Gray (1928).

Viewing the matter from a more generalized standpoint, but with fundamentals in mind, Gray (1928) and Schmitt (1944) liken the process involved to that of muscle, and consider the basic phenomenon to result from a change of distribution of water molecules "between polar groups in fibrous proteins and ionogenic groups in the environment" (Schmitt). In other words, if the proteins in the fibers along one side of the flagellum suddenly take on great numbers of water molecules at the expense of the opposite side of the filament, the filament (flagellum) will tend to bend toward the side losing the water. This sudden affinity for water by the protein might be due to a change in the degree of ionization of the protein molecule, caused by a local production of acid. Should the acid then be neutralized, the water would again be liberated (Gray). Or it might be that the protein fiber consists of folded molecular chains which fold up further upon the addition of water, thus contracting the fiber. At any rate, we get glimpses of the possibilities.

Original Investigations

STRUCTURE OF THE FLAGELLUM

Materials and Methods

It was considered desirable to experiment briefly with the more productive methods described by other workers in the study of flagellar structure. Such techniques as those of Gicklhorn (1921), Kater (1929), Allen (1936), and Smyth (1944) are useful procedures for general study or mere observation of flagella, but contribute relatively little to a detailed investigation of the type here undertaken. On the other hand, the papers of Loeffler (1890), Fischer (1895), and Deflandre (1923) describe techniques of primary importance in the development of our knowledge of whip- and flimmer-flagella. McClung (1937, pp. 141–145) presents Loeffler's method and may be more readily available to persons attempting to duplicate some of the work done on flimmer- and whip-flagella. Vlk (1938) describes his modifications of the Loeffler technique. Petersen (1929) points out the possibilities for failure and sources of error, emphasizing the extreme delicacy required in preparation. Several authors (e. g. Bütschli, 1902; Korschikov, 1923) have failed to achieve success with the mordant technique.

Such contributions as this paper may offer to the knowledge of flagellar structure are made possible through the use of the electron microscope. Further probings with the light microscope promise but little, as the possibilities have been rather carefully covered. For previously employed methods of preparation of specimens for electron microscope examination, see Marton (1941, 1943), Morton and Anderson (1942), Mudd and Anderson (1942), Richards and Anderson (1942), Prebus (1944), Williams and Wyckoff (1944, 1945 a, b), Claude and Fullam (1945), and Porter, Claude, and Fullam (1945). Some of the techniques described are adapted to specialized situations, but they bring out various points of importance in the preparation of biological material for electron microscope study. Among the most important of these, perhaps, are the removal of salts and other matter which might crystallize upon or otherwise obscure or mar the specimens, and the thinness

of film plus specimen, which should total less than 50 mμ in thickness. A good discussion of the limitations of the electron microscope for biological work in general is given by Richards and Anderson (1942). For basic principles and general limitations of the instrument, see Hillier and Vance (1941), or such popularized books as Burton and Kohl (1942) or Hawley (1945).

Dellinger (1909) and Porter, Claude, and Fullam (1945), among others, consider osmic acid the best killing and fixing reagent for retaining original appearances. I have found it extremely useful in this work. Over a dozen different procedures have been employed, the most successful of which have all involved the use of osmic acid. Formalin as a fixing reagent has apparently resulted in excessive clumping, but this has not been thoroughly investigated. Other major difficulties in the preparations were due to too many or too few organisms on the film, crystallization, loss of flagella in centrifuging, and, most of all, disruption of membranes or films under electron bombardment.

The principal organisms studied were *Astasia klebsii* Lemmermann, *Euglena gracilis* Klebs, *Ochromonas variabilis* Meyer, and *Chilomonas paramecium* Ehrenberg which were obtained from pure cultures maintained in the Protozoology Laboratory at The Ohio State University.

The film and screen upon which specimens were to be mounted was prepared as follows (slight modification of method employed by Prebus):

(1) 300 mesh/inch bronze screen is cleaned by immersing in dilute HCl and washing a number of times in distilled water.

(2) Rectangular pieces about 6 x 18 mm. are cut from the screen and kept dust-free (e. g., in a Petri dish).

(3) A vessel (e. g., a Pyrex pie plate) of about 10-inch diameter with a level rim is filled to the brim with distilled water.

(4) The water is saturated with amyl acetate.

(5) A drop or two of 2% collodion (cellulose nitrate) in amyl acetate is allowed to fall upon and spread over the surface of the water.

(6) After a few seconds a film is left, subsequent to the evaporation of the solvent. This film is then swept off by means of a glass rod, in order to clean the surface of the water. This may be repeated if it seems advisable.

(7) A drop of the collodion solution is allowed to fall an inch or less onto the surface of the water.

(8) A rectangular piece of screen, held in an artery clamp, is immersed in the water near the rim of the vessel, moved over beneath the film, and raised directly up. If parts of the film do not tear neatly around the edge of the screen, they may be severed with a needle tip by running it along the edge of the screen.

(9) Excess water is removed from the screen and film by touching the droplets with a folded corner of filter paper.

The film thus mounted on the rectangle of screen may be used immediately or allowed to dry before having specimens placed upon it. Immediate use seems preferable.

Of the techniques employed in the preparation of specimens, the following were most successful:

1. (a) Place 4.5 ml. of a pure culture of the desired organisms in a centrifuge tube.

(b) Add and mix 0.5 ml. of 2% osmic acid or 2% osmic acid in 1% chromic acid.

(c) Add 5 ml. of distilled water and centrifuge 30 seconds.

(d) Decant, then refill to 10 ml. mark with distilled water.

(e) Re-suspend organisms by rolling tube between palms of hands.

(f) Centrifuge 30 seconds.

Repeat (d) to (f) inclusive once more.

(g) Decant, then add distilled water to raise meniscus to the 0.5 or 1.0 ml. mark. Again suspend organisms by rolling the tube vigorously between the palms

(h) Place a drop of the liquid containing the concentrated, washed organisms upon film-screen and allow the organisms to settle for 30–60 seconds.

(i) Carefully remove some of the excess liquid from the top of the drop by touching to it the folded corner of a piece of filter paper.

(j) Allow to dry, then examine under compound microscope for promising specimens. An average of about 1 organism per "pane" or mesh of the film is the optimum concentration of specimens. If much more numerous, the film does not support them when under electron bombardment. If much less numerous, the specimens are too difficult to find in the electron microscope.

(k) Place screen, specimen side down, upon a rectangular piece of heavy onion-skin paper which is conveniently larger than the piece of screen. With a screen rectangle of 6 x 18 mm., a paper rectangle of about 12 x 30 mm. is of convenient dimensions. (See Fig. 17.)

(l) Flatten the screen against the paper and secure it there by means of small pieces of Scotch tape (thin, transparent, cellulose adhesive tape).

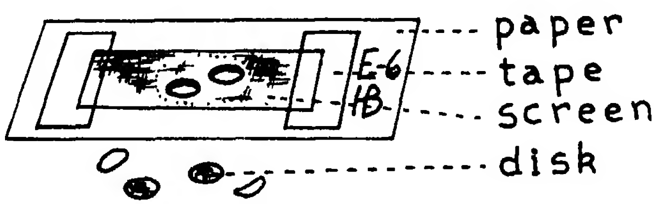

Fig. 17. See text for explanation.

(m) Label one end of the paper for identification and reference to procedure, as in Fig. 17: "E-6, HB."

(n) Place in a Petri dish or between concavity slides to keep perfectly clean, and remove to the electron microscope laboratory.

(o) Using a die constructed for the purpose, punch out circular disks of screen about 2 mm. in diameter.

(p) Separate disks of screen from those of paper and examine under compound microscope (on a clean slide).

(q) Select promising disks for electron microscope examination.

2. The following method, since it does not involve centrifugation, subjects the flagella to less drastic treatment, but requires a greater initial concentration of organisms in the culture. Various modifications of this method were employed, some eliminating step (b).

(a) Fill depression of a concavity slide with an especially rich pure culture.

(b) Add several drops of Gicklhorn's stain (made by adding about 5 drops of concentrated NH_4OH to 50 ml. of 0.05% methylene blue solution).

(c) Let stand about 1 minute and add 1 drop of 2% osmic acid in 1% chromic acid solution.

(d) Allow organisms to settle for 30–60 seconds, then touch the surface of the liquid with a folded corner of filter paper to remove excess liquid.

(e) After removing a large part of the liquid as above, carefully replace this liquid with distilled water, by means of a pipette.

Repeat (d) and (e) at least 5 times, to wash the specimens of acid and of salts, extraneous material, etc.

(f) Observe under a compound microscope (16 mm. objective) while drawing organisms into a micro-pipette. They will be concentrated in certain areas at the bottom of the drop.

(g) Deposit by means of this pipette as many of the organisms as possible in a medium-sized drop upon a film-screen mount.

(h) Allow organisms to settle, then remove excess liquid as in (d).

Continue as in (j) to (q) inclusive, technique No. 1.

Both of the above techniques were essentially developed by the author in the course of this work, as were various other less successful ones.

Results

Upon the development of satisfactory techniques, it was possible to demonstrate a number of details relative to the structure of the flagellum. Some of the more satisfactory and instructive of the electron micrographs obtained are shown in the appended plates. In viewing these photomicrographs, the reader should bear in mind that the objects and details perceptible are not rendered so by staining, as in preparations for the light microscope, but are visible because they have diffracted or absorbed varying proportions of the electrons passing through them. Thus a body appears dark because it is denser or thicker, or both, than the surrounding substance, and not because it has been differentially stained. From a careful examination of these plates, the following points may be observed:

(1) Each flagellum is of approximately uniform diameter throughout its entire length (Plates 4; 6; 9; 10; 11; 12).

(2) Each flagellum consists of a denser axial core (axoneme) and a less dense sheath surrounding the core (Plates 2 to 8 inclusive).

(3) In the flagella of *Euglena* and *Astasia*, the axial core appears to consist of two closely approximated fibers of equal size (Plates 1 *B*; 2 *A*; 4; 5; 6; 9).

(4) The sheath appears to contain or to consist of a coiled fiber which encircles the axial core in the form of a helix (Plates 1 B; 3 *A*; 12).

(5) The flagella of *Euglena* and *Astasia* bear, along one side, what appears to be a single row of delicate filaments extending from the sheath. The length of the filaments is about 5 or 6 times the diamater of the flagellum, or 1.5 to 2.0 μ. (Plates 1 *B*; 4; 9).

(6) The long flagellum of *Ochromonas* bears similar filaments along both (all ?) sides (Plates 11; 12).

(7) The flagella of *Chilomonas* bear no such lateral filaments (Plate 10).

It is possible that the ground substance or intermediate substance which might be expected to occur between axial fiber and sheath, perhaps comprising a large part of the bulk of the living flagellum, has escaped in most of the specimens shown. Consideration of Plate 7 might lead us to this conclusion, assuming the darker upper portion of the flagellum to represent a region which, somehow, had not yet lost the inner plasm. Perhaps the swollen appearance in Plate 8 is due to an accumulation or exudation of such matter during the drying of the specimen. From Plate 7 we also get an indication that the lateral filaments might possibly be due to the escape (and subsequent coagulation) of plasm from a lateral series of minute pores. In view of the work of Vlk, who demonstrated flimmer upon a living flagellum, this explanation might be held to apply to the possible origin of flimmer in the living organism. In such a case, complete coagulation might not occur until death.

A second possible explanation for the appearance shown in Plate 7 is that a portion of the flagellum might have contracted, bringing the coils of the helix into closer approximation and producing the denser and thicker appearance seen in the upper portion of the flagellum shown. It is difficult to determine precisely what actually happened to produce this effect, and the interpretation of such an appearance must remain uncertain for the present.

Upon inspection of the plates, it will be noted that, as stated in (1) above, the flagella depicted are of approximately uniform diameter throughout their entire length. Little, if any, tapering occurs at either extremity. Emmel, Jakob, and Gölz (1942) report the same condition in electron micrographs of ***Leishmania donovani***.

Of the other points listed above, (2) simply substantiates the generally-accepted notion of flagellar structure. (4) serves to emphasize the similarity between the protozoan flagellum and the mammalian sperm tail, as described by Schmitt and others. (5), (6), and (7) corroborate, by an entirely new technique, the findings of a number of workers, extending somewhat the knowledge of the details.

Unfortunately, many of the best "shots" were lost, due to the rupture or the supporting film or the sudden curling up of flagella under the impact of the electron bombardment, before photographs could be taken. However, the fact that a flagellum, even though flattened out against the film, in a high vacuum (0.00001 to 0.0001 mm. Hg.), and dead for many hours, can retain within itself the potential ability to tear itself loose and curl up like a watchspring, may be significant. Similar coiling during the disintegration of flagella has been described by several investigators (e. g., Fischer, 1894), but never with violence like this.

The photographs included in this paper were, of course, selected to bring out various points. Plate 6 shows an entire flagellum, about 13 μ in length, extending from the body of the euglena. The flagellum is seen to extend, not from the anterior tip of the organism, but from a point slightly lateral and posterior to the tip, where it emerges from the mouth of the gullet. Plate 6 also shows the naked axoneme, where the supporting film has torn, snapping the flagellum off near its base. Plate 2 *A* probably represents a flagellum lying adjacent to the body, and extending away from it near the posterior tip of the body. Plate 2 *B* gives an indication of the relative strength or durability of the axoneme and the sheath, the axoneme being apparently stronger and more elastic.

Plates 4 and 9 display especially well the single flimmer-row on the flagellum of ***Euglena***, and represent flagella prepared by different techniques. Plates 11 and 12 show flimmer along both sides of the long flagellum of *Ochromonas*, which might, in life, occur either in two opposite rows or all over the surface of the flagellum like the hairs on a dog's tail. It will be noted that the flimmer do not occur in the neatly regular rows depicted by previous workers. This may be accounted for by the fact that these specimens have been centrifuged several times in preparation, a drastic measure not employed by previous workers. Such a disarrangement should be expected.

Plate 9, in portions depicting twisting, shows clearly the two major fibers of the axoneme in the flagellum of ***Euglena***.

Plate 3 *A* indicates the helical structure in the sheath rather well. Such plates as 2, 5 and 7 also suggest this helical structure. Other plates, in which the sheath does not stand out perceptibly from the axoneme, may be of interest in that there occur at more or less regular intervals along the sides of the flagellum dark spots which may represent the helix closely appressed to the axial core. Plates 1 *B*, 9, 11, and 12 show such indications. If this is the correct interpretation of such appearances, the pitch of the helix on the flagellum of *Ochromonas* is considerably greater than that of ***Euglena*** (i. e., the coil is less tightly wrapped, forming longer spirals). Further, if this be the correct interpretation, the spots shown in Plate 9 will be of especial interest. Many of them are lighter in the center, indicating that the coiled fibril may be hollow or tubular.

Plate 1 *A*, which is an electron micrograph of a diatom, is included to show our method of computing sizes. Large numbers of this type of diatom, a species of ***Gomphonema***, were collected several years ago, cleaned, and calibrated. Lateral transverse rows of pores may be seen extending from a median longitudinal solid

area like the barbs in the vane of a feather. The pinnate rows along one side of the median line are usually more nearly perpendicular to the axis of the median line than are the rows along the other side of the line. The average distance between consecutive rows is about one-third of a micron. We obtain measurements by averaging the distances between every fourth row. This average is about 1 μ. After taking a series of micrographs at a given magnification, a diatom is photographed at the same magnification, in order to provide a scale for measurement. This method and the initial calibration of the diatoms were worked out by Dr. Prebus.

MECHANICS OF THE FLAGELLUM

Observations on Living Organisms

Flagellar action is, in most cases, very difficult to observe in normally-moving or freely-swimming creatures. The flagellum is hard enough to see when still, and when in active motion is beyond the capabilities of the human eye. For this reason, most studies on living flagella have been made on organisms under abnormal conditions. They have been chilled, anesthetized, compressed, placed in viscous media, or simply observed in the latter stages of approaching death, when the water beneath the cover glass was drying up. Realizing that normal activity is hardly to be expected under such circumstances, yet assuming that certain basic phenomena should remain constant, I have made a few observations under some of the above-mentioned conditions.

The most convenient method I have found for rendering flagellar motion visible involves the use of methyl cellulose (Methocel, Dow Chemical Co.). A drop of 10% solution of this substance is mixed on a slide with a drop of culture, then a cover glass added (Marsland, 1943). The resulting mixture, of rather high viscosity, slows down the strokes of flagella or cilia, and also is of a very different refractive index from water, such organelles becoming much more easily visible than in water.

Among the structures observed by this method were the flagella of ***Peranema trichophorum***, ***Euglena gracilis***, and ***Trichonympha*** sp., the undulating membrane of a trichomonad from the gut of ***Reticulitermes flavipes***, and the cilia of ***Paramecium*** sp. The optical system employed included a Spencer 4 mm. objective (N.A.—0.85) and a 20 × Planoscopic ocular, with a resulting magnification of about 880 ×. In every case, the wave impulse traveled from the base toward the tip, in a spiral course, producing rotation of the tip. All of these observations directly confirmed certain conclusions of Lowndes (see historical review). In ***Euglena*** the flagellum was usually directed back more or less along the body. I was somewhat surprised to find this sort of movement in cilia, as I expected to see the paddle-stroke described by Gray and others. However, the cilia were observed to alter the direction of their strokes quite readily, beating forward, directly outward, or backward (and toward or away from the observer). The spiral, flagellum-like stroke or undulation was most conveniently observed when the cilia were beating directly outward, or away from the body surface. The cilia beating thus created a current away from the body. I have wondered whether this spiral undulatory stroke in cilia might be due to the greater density or viscosity of the medium employed in these experiments. Cinematic photography of such cilia under more nearly normal conditions should aid in clearing up the matter. Alverdes (1922) made an extensive study of ciliary movement in several species of ***Paramecium***, ***Stentor***, etc. He ascribed to the cilia considerable versatility of movement. He also described interesting experiments on the shedding and regeneration of cilia by ***Paramecium***. He kept the organisms in a 0.1% solution of chloral hydrate for about 48 hours, then transferred them to fresh water, and, after 3 to 9 hours, observed the regeneration of the cilia. The cilia began beating when only stubs.

This technique, combined with good cinematic photomicrography, might produce very interesting results.

I have observed, without altering the medium in any way, flagella in colonies of *Volvox* which seemed capable of performing almost any movement possible for a filament attached at one end. Since the colony was probably suffering under adverse conditions, the movements probably were not normal, but they certainly served to emphasize the versatility of movement possessed by the flagellum. To quote again from Krijgsman's summary (translation): " . . . its movements at times can not be explained according to simple mechanical principles." It is too easy to agree with him.

Experiments on Locomotor Mechanisms.

"ARTIFICIAL FLAGELLATES." In order to test the forces produced by rotating and gyrating objects, a device was worked out as shown in Fig. 18, whereby structures comparable both to bodies and to flagella of flagellate organisms could be studied in this connection. Originally it was devised for comparison with a flagellum, but when the significance of Lowndes's hypothesis became apparent to me (upon the receipt of his later papers), it was extended to a study of body gyration.

This hypothesis, it will be recalled (see historical review), suggests that *the major component of force producing the forward locomotion of a monoflagellate results from the rotation and gyration of the body of the organism*, and not directly from the action of the flagellum. Consequently, a model was constructed in the shape of a sample protozoan (e. g., see Fig. 22) in order to test the locomotor effect produced by the rotation and gyration of such a body. As figured in the accompanying diagram, *B* represents this body, with *a* representing its axis. The arrows encircling the axis of forward progression *A* serve to indicate the path of gyration of the body axis *a*. All of the rest of the diagram below the body *B* is simply included to show how the rotational and gyrational force is applied to *B*.

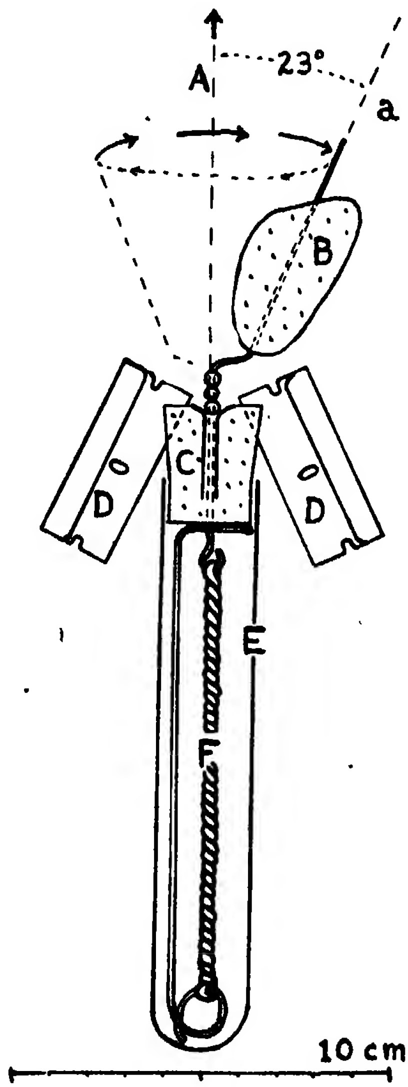

FIG. 18. Diagram of the "artificial flagellate." *B* represents a model of a monad body, which rotates and gyrates about its axis of progression, *A*. *a* represents the body axis. The lower part of the diagram merely indicates the apparatus employed to impart to the body *B* its rotational and gyrational force. See text for explanation and discussion.

Thus in Fig. 18, *A* represents the axis of gyration and progression about which the cork body *B*, with axis *a*, is caused to rotate and gyrate. In the diagram, the body is gyrating clockwise as seen from the base or rear. (Throughout

this paper, when the terms clockwise or counter-clockwise are employed, reference is made to the rotational path of the distal gyrating extremity as viewed from the apex of the gyrational cone.) A heavy rubber band, *F*, twisted in the desired direction, produces the rotation which, in turn, causes the part of the wire bent out of line to gyrate. It was often found desirable to use two rubber bands, in order to obtain greater speed and force. Beads below the bend in the wire served as bearings, and turned in the funnel-like flared end of a metal tube which was inserted in the cork stopper *C*. Since the rotation and gyration of *B* caused the base (*C*, *D*, *E*, etc.) to rotate and gyrate in the opposite direction, it was found necessary to reduce such rotation considerably; otherwise, the rubber band rapidly became untwisted. Two razor blades, *D*, inserted in the cork parallel to axis *A*, served as fins or keels in reducing rotation of this portion of the system. In order to balance the system to a specific gravity slightly above 1.0, water was added to test tube *E* in the necessary amounts. Paraffin was found to be less satisfactory in achieving this balance. The angle (β) between *A* and *a* was altered simply by bending the wire. The body, *B*, may be replaced by other objects of diverse shapes and sizes.

1. Currents produced in fluids by gyrating structures. Experiments were performed with the "artificial flagellate" using smoke, in air, and minute suspended particles, in water, to observe the currents produced by the gyration of *B*.

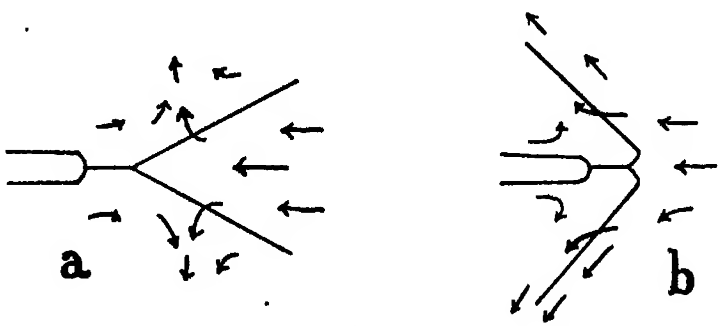

FIG. 19. Currents produced by gyrating wires in water. (Redrawn from Metzner, 1920, Figs. 3, 4.)

The results of these experiments, which were not extensive, were in accord with those of Metzner (1920). In brief, if the path of gyration forms a simple cone, fluid is drawn into the cone primarily from its base, departing near the apex (Fig. 19). Thus a major current is produced toward the base of the cone in the surrounding medium. If the body were free to move, it would progress toward the base of the cone. Lowndes (1944 b) has also demonstrated rather fully the action of similar objects. For theoretical considerations as to the mode of function, see Metzner, (1920, pp. 53–58).

2. Locomotion of gyrating systems in water. A number of experiments were performed to determine the velocity achieved by the "artificial flagellate" in water, relative to the shape and position of the body *B*. In each case, both clockwise and counter-clockwise gyrations were tested, in order to eliminate such factors as the possibility that the razor blades (*D*) might be acting as screws or propellers. These experiments were carried out in a greenhouse tank (200 x 80 x 60 cm.).

It was found that when structures much larger than *B* were placed on axis *a* to gyrate, the rear end of the test tube *E* was caused to gyrate considerably. Since this would exert a force in the opposite direction, it was objectionable. By placing

around the test tube a fairly close-fitting, rigid jacket, this gyration may be minimized. A coarse screen or hardware cloth is perhaps best, although a test tube slightly larger than E was first used for the purpose. In the latter case, there is too much difficulty involved in the movement of water to fill the space vacated by the progressing system. In the set-up as shown in the diagram, the gyration of the test tube was sufficiently unimportant to be neglected in the gross observations being made.

Velocity was measured horizontally and vertically. The latter measurements represent much freer motion on the part of the "flagellate," but are more difficult to obtain under the conditions encountered. The "organism" is balanced so that it sinks rather slowly. Then, wound up, it is held down, allowed to gyrate a few times, and timed on its way up (its stable position is in the vertical axis). For the most part, it was timed through a distance of 20 cm. A stop watch was used in all cases. Horizontal runs were made by placing the test tube in some such jacket as mentioned in the preceding paragraph and holding the jacket steady in the horizontal plane. By the nature of this set-up, such runs were confined to a distance of 5 or 6 cm. Since, in every case, B was buoyant, the gyration was uneven in this plane. Another factor necessitating brief runs, both horizontally and vertically, is that the force producing the gyration diminishes rapidly as the rubber bands untwist. In consideration of these, and perhaps other conditions, it is obvious that the measurements are necessarily inaccurate. To assume an error of $\pm 10\%$ would be optimistic. However, the figures are at least indicative, and have some value thus.

Relative speed, as here employed, equals distance traversed by the organism in one second divided by the length of the gyrating body. Thus, if the body B were 5 cm. long and the system moved at 10 cm./sec., the relative speed would be $10 \div 5$, or 2. Among Protozoa which have been actually timed for rate of swimming, the relative speeds vary from 0.25 (*Euglena terricola*, Günther, 1928) or less, to 40.0 (*Monas stigmatica*, Lowndes, 1944 b, 1945 a) or more.

With a long body (B), 14 x 1 x 1 cm., at 1 to 1.1 gyrations/second, traveling horizontally out of a vial, with angle β at 23°, the maximum constant velocity observed was 1 to 1.2 cm./sec., representing a relative speed of about 0.08. Using the same set-up, but with angle β greater than 90° (see Fig. 19 *b*), the maximum velocity was 0.33 cm./sec. This condition hardly corresponds to any natural one.

With a short body (B) as shown in the diagram, 4.7 x 3.7 x 2.4 cm., at an estimated 6 gyrations/second, traveling vertically, with angle β at 23°, the maximum constant velocity was 25 cm./sec., representing a relative speed of about 5. With angle β at 15.2°, a maximum velocity of 33 cm./sec. was observed. This was under ideal conditions and was never quite duplicated. It represents a relative speed of 7, the highest obtained in these experiments.

To test the forces produced by a flagellum undulating in a helix or spiral, the body, B, was made in such a shape by bending a wire and coating it with 1.5 to 2.0 mm. of paraffin. The form was approximately that shown in Fig. 16, but with a less complete pitch. The complete pitch would be about 20 cm. The flagellum rotated at about 18 turns/sec. With the flagellum rotating counter-clockwise, the system moved forward at 34 to 38 cm./sec. With the flagellum rotating clockwise, the system moved backward at 20 to 22 cm./sec. If a living flagellum beats from the base outward, the latter is the only type of motion compatible with the system. In order for an actual flagellum to execute a movement similar to the former, the wave of contraction would have to begin at the tip of the flagellum. If this occurred, it would constitute a "tractellum." It probably does *not* occur in nature.

From our experiments with the "artificial flagellate," we learn that the mere rotation and gyration of a body in water can provide sufficient force to produce rapid forward locomotion of the body. This greatly strengthens the hypothesis advanced by Lowndes (1944 a).

UNDERWATER SWIMMING. These experiments test, in a fashion, the strength of the "pull" exerted by gyrating structures. In contrast with flagellate bodies, but like the flagella themselves, the gyrating objects do not necessarily rotate. The arms of the swimmer serve as the gyrating structures. The rate of gyration is approximately 1/sec. The gyrating portion is 60 cm. in length. Figures on velocity are computed from the distance traversed in about one-half minute. The body weight of the swimmer is about 130 lbs. or 59 kg. In each case, enough air has been expelled from the lungs to allow the body to sink to the bottom of the pool. All experiments were performed by the author. Timing was done by an observer with a stop watch.

(1) The body is horizontal, with one arm extended horizontally forward and gyrating, e.g. clockwise, in a relatively narrow cone. (Fig. 20 *a*) Result: the body moves horizontally forward, rotating counter-clockwise, in this case. Velocity, 10+ cm./sec. Relative speed, 0.16+. Total distance progressed, 10 ft.

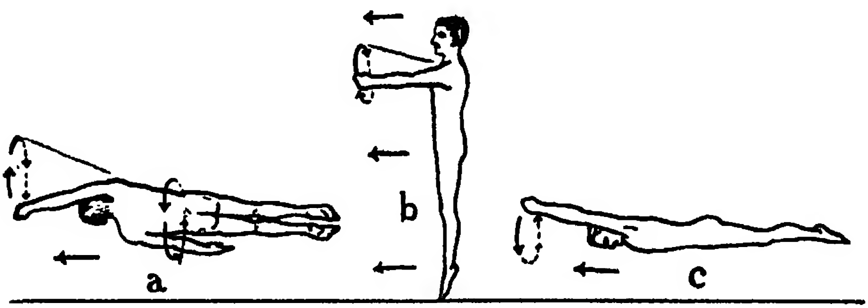

FIG. 20. Underwater swimming experiments. See text for explanation.

(2) The body is vertical, with both arms extended horizontally forward, the right gyrating clockwise, the left counter-clockwise or *vice versa*. (Fig. 20 *b*) Result: the body moves horizontally forward, not rotating. Velocity, 10+ cm./sec. Relative speed, 0.16+. Total distance progressed, 10 ft.

(3) The body is horizontal, with both arms extended horizontally forward, the right gyrating clockwise, the left counter-clockwise. (Fig. 20 *c*) Result: the body moves horizontally forward, not rotating. Velocity, 33 cm./sec.. Relative speed, 0.55. Total distance progressed, 32 ft. Reversing the gyrations, the velocity is considerably less, being at most about 23 cm./sec., with a relative speed of about 0.39. Total distance progressed, 22 ft. This may well be due to an unintentionally weaker stroke, as it is more difficult and tiring to the experimenter.

(4) The body is in the same position as (3), but both arms are gyrated in the same direction. Result: the body rotates in the opposite direction at approximately the same rate, little forward movement being accomplished.

(5) The body is in position (3), but the arms are pendulated or swung back and forth in one plane, instead of being gyrated. Result: no detectable forward component.

Minor components are omitted in this consideration, for the sake of simplicity. In many cases they are results of the musculature of the arm.

Other experimental positions were tried, but contribute no additional significant data and are hence omitted.

The results of these experiments provide additional evidence in support of Lowndes's hypothesis. They serve further, however, to show that rotation of the gyrating object is not necessary to the production of a forward component. *Mere gyration of an object* (an arm or a flagellum) *can produce an effective locomotor force.*

Discussion

From the historical review given in this paper, it is apparent that a considerable mass of knowledge has been accumulated on the subject of flagellar structure, but that, in large part, the data have not previously been assembled and organized. Certain phases of the subject, to be sure, have been well summarized. For instance, Vlk (1938) treats whip- and flimmer-flagella as such rather thoroughly, but neglects the internal structure. However, he is not to be criticized for this, as little new knowledge has appeared relative to the matter within several decades. The subject has awaited a new technique which could permit of more minute investigation. The electron microscope provides this new angle of attack through its much greater resolution and magnification. This paper presents the results of the first intensive study of the protozoan flagellum employing the electron microscope.

By means of this instrument, we find that the flagellum, at least in the forms studied, consists of a dense fibrillar axial region and a surrounding sheath of much less density. This much has been previously accepted, though never before so clearly demonstrated. Just how many fibrils there are comprising the axoneme, I cannot tell. The number probably varies to some extent. The sheath seems to contain a fiber which encircles the axoneme in the form of a helix. This sort of composition of axoneme and sheath appears to be in close agreement with the structure of mammalian sperm tails as described by Schmitt and others, but has never before been described in the protozoan flagellum, unless the brief remarks of Ŭlehla (1911) be considered such. Unlike the sperm tails, certain flagella possess lateral or terminal external extensions of the sheath. These structures have been recorded since 1889, but are not yet universally accepted by protozoologists. Several electron micrographs of the lateral structures in question (the flimmer) are included in this paper (e. g., Plates 4, 9, 11, 12). Of course, such pictures constitute no conclusive proof of the nature, or even natural occurrence, of the flimmer. But they certainly contribute to the evidence in favor of their acceptance as normal structures, rather than as artifacts. If Vlk had had at his disposal the equipment of Lowndes (1935), Harvey and Loomis (1931), or Pijper (1940), perhaps the question might have been settled for the most skeptical by the actual photographing of flimmer on living flagella. However, the facts that they have been demonstrated by a number of basically different techniques, on dried or moist flagella, following various fixatives or none at all, and that they are amazingly constant in appearance, position, etc., place the overwhelming weight of evidence in favor of the view that they represent normally-occurring structures in many types of organisms. The presence and type of flimmer or whip comprise valuable taxonomic characters, and will doubtless be so considered when they are more readily demonstrable.

There are a number of devices as yet untried in the study of these structures, some of which should certainly contribute to our knowledge of their nature. I mention them in the hope that someone, to whom they may be available, may be interested in furthering this study. By means of the shadow technique of Williams and Wyckoff (1944, 1945 a, b), the flimmer should be made obvious. A study of living flagella might be made with the ultra-violet microscope (Lucas, 1930, 1934; Schmitt, 1939; Lavin and Hoagland, 1943), whereby twice the resolution of the ordinary microscope might be obtained. Phase difference microscopy (Richards, 1944) offers interesting possibilities in the study of living flagella, yielding the benefits of stains and fixing reagents, as does the ultraviolet microscope, without requiring the use of such deleterious agents. (That is, it serves to differentiate structures and substances which we commonly bring out only by staining.) Fluorescence microscopy (Ellinger, 1940; Metcalf and Patton, 1944) also gives promise, especially, perhaps, in the study of flagellar motion. If nat-

urally fluorescing flagella occur, these would be ideal for such a study, but a fluorescent vital stain such as Fluorescein might serve well.

It is interesting to view the results of Kunstler and Fischer in the light of details brought out in electron micrographs. If the reader will again refer to Fig. 1, he may notice certain similarities to some of the plates. The interpretation of the appearances, however, is rather different. The axial canal of Kunstler is probably the axoneme. Plate 7 shows, in places, an apparent breaking up or segmentation of the axoneme into pieces resembling the "vacuoles" of Kunstler, as seen in Fig. 1 *a*. Figs. 1 *b* and *c* are reminiscent of the helix of the sheath as seen in the electron micrographs, the corrugations depicted by Kunstler probably representing the surface appearance of the structures. It must be borne in mind that Kunstler had at his disposal nothing like the resolution and magnification of the electron microscope; his observations were remarkably good, in consideration of this fact. Segmentation of the flagellum may somehow be produced by the action of osmic acid, in combination with other factors. Kunstler had used this reagent in his preparations, as have I. Gelei (1926) showed that such appearances resulted from certain reagents, among them osmic acid in combination with other chemicals.

Fischer apparently found a continuous axoneme in many flagella, but took great pains to demonstrate or argue that it was but an artifact. He, too, did a good job with what he had, and presented a rather convincing argument. However, in the light of evidence since brought forth, including much in this paper, it is highly probable that he was mistaken in his interpretation of at least the nature of the axial fiber.

Regarding the structure of the flagellar filament, Plate 7 presents an interesting picture, which, as Dr. Prebus points out, may well represent at the denser end the natural appearance of the flagellum. Here the helical structure in the sheath is evident, but the inner axial fibers are obscured by the density of the surrounding matter within the sheath. In the less dense portions of this filament we see what is perhaps the result of a loss of material from the sheath or intermediate substance. This lighter portion corresponds to the appearance of most of the flagella shown, and brings out the internal structure, but may thus represent a state of disintegration of the flagellum.[3] The ground substance which may have escaped is precisely that which is considered to be the contractile portion of the flagellum by many workers. For my part, I find it easier to attribute the major contractility to the fibrillar structures remaining.

In this connection, I might mention a possible mechanism for the progress of the contractive wave which has not heretofore been suggested, so far as I know. It has no basis in experimental evidence, and is simply proposed for consideration. Since the flagellum appears to have a fibrous core which is encircled by a helical fiber, as represented diagrammatically in Fig. 21, it is possible that the spiral fiber transmits the impulse. If along this fiber passed a wave of chemical change, comparable to that in a firecracker fuse or a nerve fiber, perhaps releasing H ions wherever it passed over the axial fibers, it could stimulate local contraction in such parts of the axial fibers as might be contiguous with it. In conjunction with twisted axial fibers (Dellinger, 1909), this might account for undulatory movements of a spiral nature. In such organisms as *Peranema*, the axial fibrils might be stiffened or less sensitive in the basal portion, thus accounting for the fact that normally only the distal part shows obvious activity, whereas, if stimulated to a

[3]A second possible explanation for the appearance shown in Plate VII is that a portion of the flagellum might have contracted, bringing the coils of the helix into closer approximation and producing the denser and thicker appearance seen in the upper portion of the flagellum shown. It is difficult to determine precisely what actually happened to produce this effect, and the interpretation of such an appearance must remain uncertain for the present.

greater extent, the entire flagellum is thrown into undulations. Also, if the axial fibrils along one side should be less reactive, the resultant stroke might be paddle-like. With a bit of imagination, this hypothetical mode of functioning can be fitted to most observed facts. At least, it fits the facts better than any other system proposed, so far as I have been able to discover. However, it remains purely speculative.

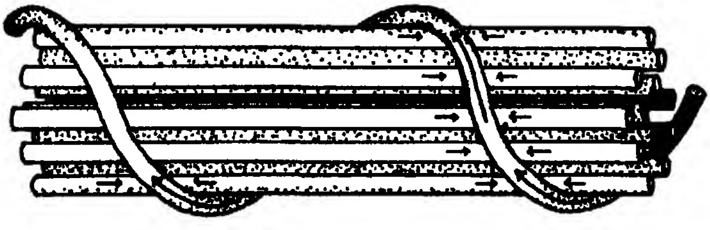

FIG. 21. Diagram illustrating hypothetical path of impulse in flagellum. See text for explanation.

Likewise in the realm of speculation to an extent, but also of interest, in a different way, is the appearance of the axial core of the flagellum of *Euglena* (Plates 2 *A*; 5; 9). There seem to be two equal fibers running side by side, which are displayed especially well where the flagellum (or merely the fibers) is twisted. These fibers are probably composed of yet finer fibrils (see Dellinger, 1909), though such are not evident in the plates. Now it happens that *Euglena* has a bifurcate flagellar root. Two distinct branches, arising from two separate basal granules, unite in the gullet at about the level of the stigma (eyespot) to form the single flagellum (Wager, 1899, et al). Hartmann and Chagas (1910), in consideration of the bipartite root, considered *Euglena* as derived from a biflagellate. It seems probable to me that the two fibers within the flagellum definitely strengthen such a view, and might be regarded as the two ancestral axial fibers or axonemes in close association.

Another interesting source of speculation is the relationship between the bacterial flagellum and that of the protozoon. Electron studies have been made on many bacteria. Among authors reproducing numerous electron micrographs of bacterial flagella are Piekarski and Ruska (1939) and Mudd and Anderson (1944). According to these and other authors, the flagella average from 14 to 50 mμ in diameter, and often occur in clumps or tufts, as they do in the spirochete *Treponema* (Mudd, Polevitsky, and Anderson, 1943). Their precise nature still appears doubtful. The suggestion has been made (e. g., Polevitsky, 1941) that they may be hollow tubes, but Mudd and Anderson (1942, p. 106) find no support for this idea in cases which superficially present such an appearance. Mudd, Polevitsky, Anderson, and Chambers (1941) figure an electron micrograph of *Bacillus subtilis* with the protoplasm shrunken away from the cell wall. On the other hand, Mudd and Anderson (1944) figure *Vibrio cholerae*, showing a "single polar flagellum, which seems to traverse the cell wall to join the bacterial protoplasm." At any rate, bacterial flagella, whatever may be their exact nature, and even though they may not arise in a tuft, often entwine to function as a unit and may even remain adherent, forming a filament composed of many fibrils and perhaps encased in a gelatinous (?) sheath. (See historical review for references.) Now recall the flagellar or sperm tail structure with its 9 to 12 fibrils, each 25 to 50 mμ in diameter, ordinarily encased in a sheath. The possibility certainly is suggested that the ancestral protozoan flagellum may have been derived from such a permanently united clump of fibrils as occurs in some of the bacterial forms. Should this prove

to be the actual phylogenetic origin of the protozoan flagellum, the concept of the fibrils as contractile units, rather than as mere elastic rods, would be definitely strengthened. However, the fibrils might well serve both as contractile and as supportive structures.

With regard to the mode of functioning of the locomotor flagellum, my observations and experiments confirm the conclusions reached by Lowndes. The living flagella observed beat in spiral undulations, the waves of contraction always progressing from base to tip. My experiments with an "artificial flagellate" and with underwater swimming demonstrated that sufficient force is produced by the simple conical gyration of a body to account for rapid locomotion toward the base of the cone Fig. 22 and its legend describe the propulsive mechanism as conceived by Lowndes. I have never, to my knowledge, watched the swimming of this particular organism, but I have observed other similar ones. From my own experiments and the work of Mr. Lowndes, I have no doubt that the gyration of the organism *could* account for a relative speed of 40 (that given by Lowndes for *Monas stigmatica*), if the body gyrated with sufficient rapidity. But in the forms I have observed, it is difficult to imagine how the body gyration alone could produce such

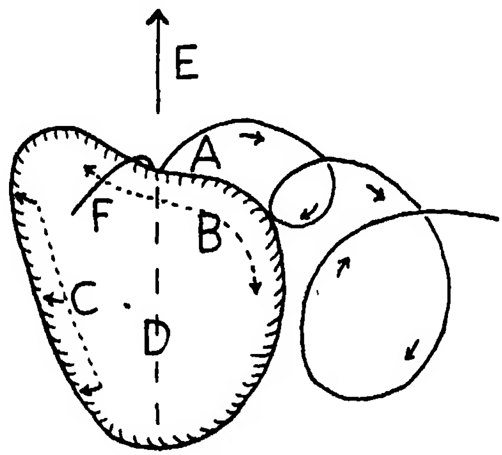

FIG. 22. "*Monas stigmatica* with its two flagella. Diagrammatic." "Waves pass along the long flagellum, from base to tip, in a spiral manner with an increase in velocity and amplitude. The force generated is transmitted to the surface of the cell at *A*. This causes the organism to rotate and gyrate about the axis *D*. (The edge *B* going below the surface of the paper and *C* being raised above it.) Thus the organism is converted into a rotating inclined plane and moves forward more or less in the direction indicated by the arrow *E*. The very short flagellum *F* appears to act as a guiding or sensory organ during normal swimming." (Redrawn and quoted from Lowndes, 1945 a.)

speed. At a rate of body gyration of only about 1/sec. the relative speed may be at least 5. I should think that the forward component produced by the flagellum would aid greatly in the attainment of high speed. But perhaps my imagination is not keyed to the physics of the micro-world of the flagellum. Apparently the mechanics and physical relationships (e. g., the relative viscosity of water, a major item in the protozoan world) to which we are accustomed are tremendously altered, practically non-existent, at this level of dimensions. For an interesting discussion of some of the differences see Bidder (1923, pp. 304–307).

Brief mention may be made of the possibility of studying living organisms with the electron microscope. It would obviously be desirable to study such a structure as the flagellum in the living, intact state. Several papers have appeared relative

to the possibility of observing living structures with the instrument, but, so far as I know, the only objects studied thus or even very practical for such study have been spores. Perhaps the most ambitious attempts have been made with the closed cell described by Abrams and McBain (1944). The obvious difficulties result from greatly reduced contrast and Brownian movement, which prevent photographing of the objects under observation. Another major factor is the killing effect (aside from heat production) due to " . . . the electrons bounding down through the specimen and breaking the chemical bonds of the specimen. Breaking the bonds is detrimental to all living organisms. Every bond in living organisms does not have to be intact, but the critical molecules in the living organisms must have a specific structure in the organism for it to grow and reproduce itself. When you consider that, in maximum intensity, the beam reaches a high value of 1,000 electrons per square angstrom per second, you can realize that it wouldn't take the scattering of many electrons to kill such an organism." (Anderson, 1943.) In terms more familiar to the biologist, this electron bombardment would amount to 100,000,000,000 electrons striking a surface of 1 square micron each second The average protozoan body would present a surface of a considerable number of square microns. Thus the prospects of studying a living flagellum, even if it were perfectly stationary and met the other requirements, would not be encouraging.

SUMMARY

1. The work of previous investigators in this field is reviewed and discussed.

2. The structure of the flagellum of several species of Protozoa has been investigated by means of the electron microscope. Micrographs are included which show that:

(a) The flagella studied are of approximately uniform diameter throughout their entire length.

(b) Each flagellum consists of a denser axial core (axoneme) and a less dense sheath surrounding the core.

(c) In the flagella of *Euglena* and *Astasia* the axial core appears to consist of two closely approximated fibers of equal size.

(d) The sheath appears to contain or to consist of a coiled fiber which encircles the axial core in a helix.

(e) The flagella of *Euglena* and *Astasia* bear, along one side, what appears to be a single row of delicate filaments (flimmer) extending from the sheath. These flimmer have an average length of about 5–6 times the diameter of the flagellum proper.

(f) The long flagellum of *Ochromonas* bears similar filaments along both (or all?) sides.

(g) The flagella of *Chilomonas* bear no such lateral filaments.

The significance of certain details present in the electron micrographs is discussed.

3. The presence of two equal fibers in the flagellum of *Euglena*, together with the fact (demonstrated by previous investigators) that the flagellum of this form has two separate roots, indicates the ancestral formation of its flagellum by the fusion or union of two flagella. The hypothesis of a biflagellate ancestry of *Euglena* is strengthened.

4. The possibility of the origin of the primitive protozoan flagellum through the union within a common matrix of several simple fibrillar flagella (as are present in certain bacteria) is suggested. Evidence for such a theory is presented.

5. Observations were made on the activity of living flagella. The results were in direct confirmation of Lowndes's contentions that:

(a) The flagellum beats in spiral undulations.

(b) The waves of contraction progress from the base toward the tip of the flagellum.

(c) As they progress, the waves often increase in amplitude.

(d) The flagellum usually serves to push, rather than to pull the organism through the water, although it arises from the anterior end of the body.

6. Experiments were performed by means of actual underwater swimming by the author and with an "artificial flagellate" to determine the forces produced by gyrating bodies in water. In both cases, a simple conical gyratory movement was found sufficient to produce locomotion. Employing the artificial flagellate, it was found that rotation and gyration of a small body at about 6 gyrations per second was capable of producing a relative speed of as much as 7.0 (i. e., 7 lengths per second), in spite of the fact that the body had to pull along after it an object much larger than itself. This confirms the theory of Lowndes that the rotation and gyration of the body alone may adequately account for the locomotion of many flagellates, without any forward component produced directly by the flagellum.

7. A hypothesis is suggested concerning the mechanism of flagellar function: Perhaps the helical fiber of the sheath transmits an impulse which stimulates local contraction in the underlying fibrils. Possible ways by which such a mechanism might account for the various types of flagellar movement are mentioned.

8. Promising techniques, recently developed in other fields, are suggested for further research on flagella.

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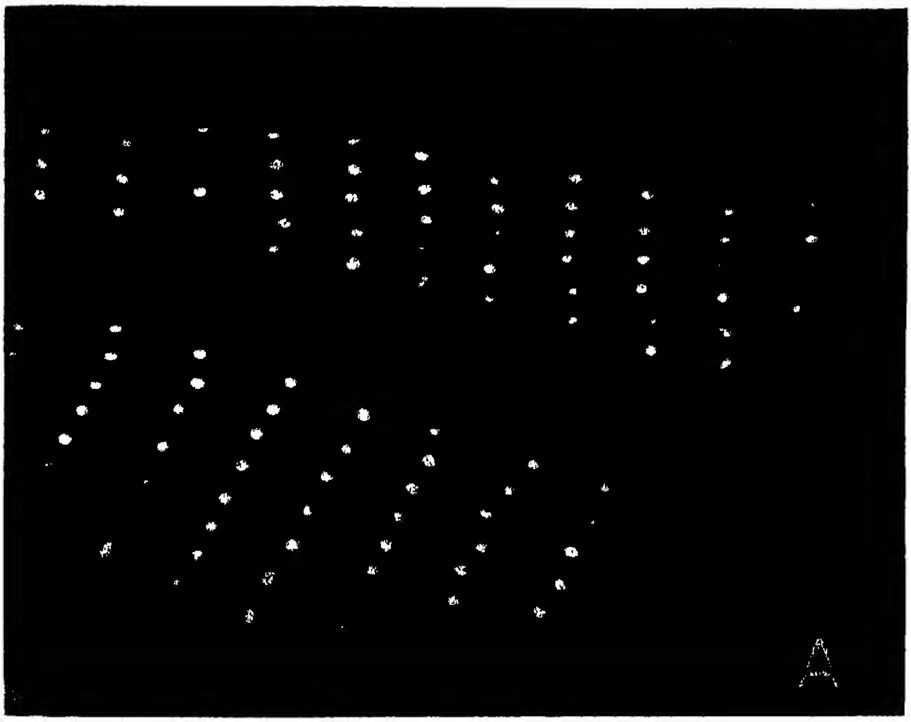
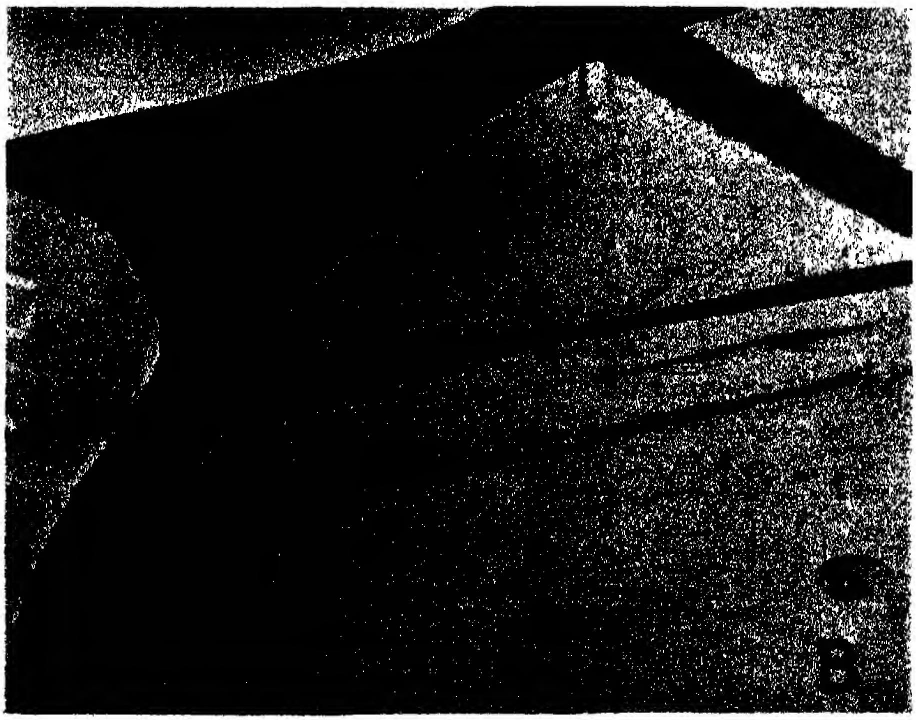
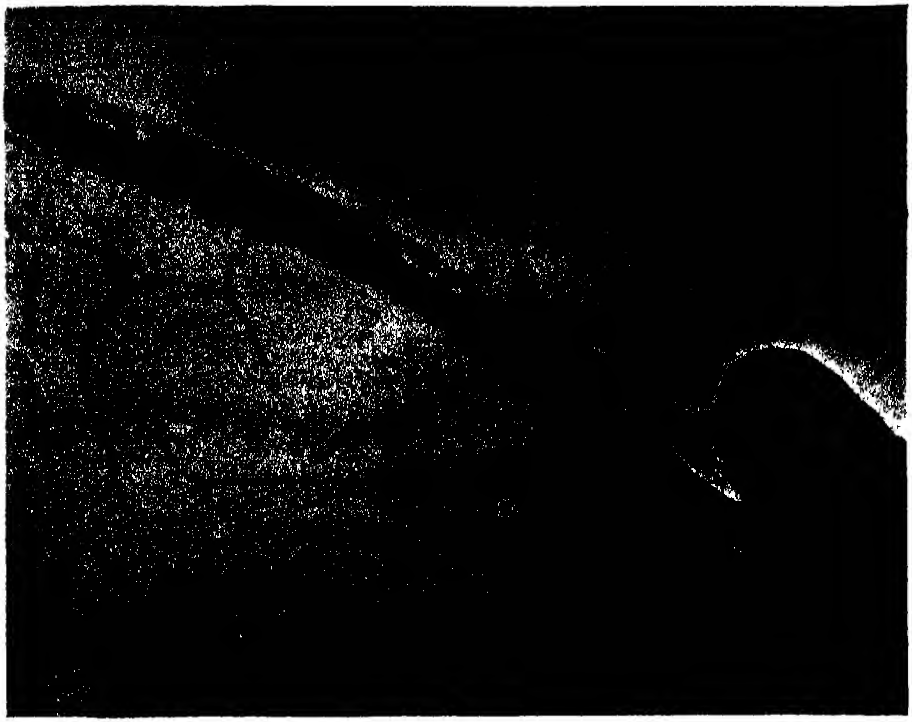
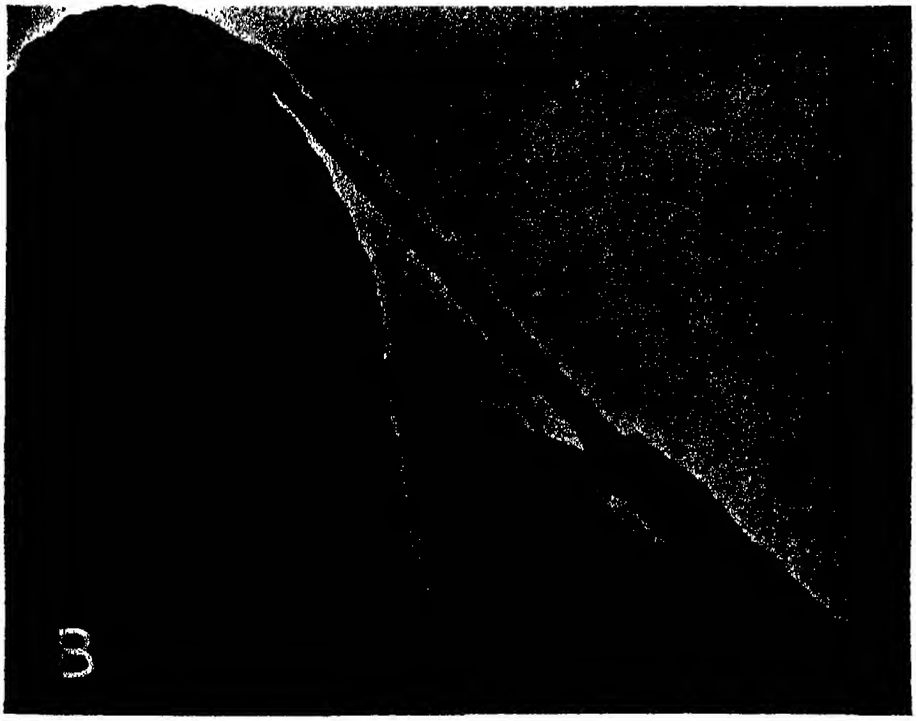


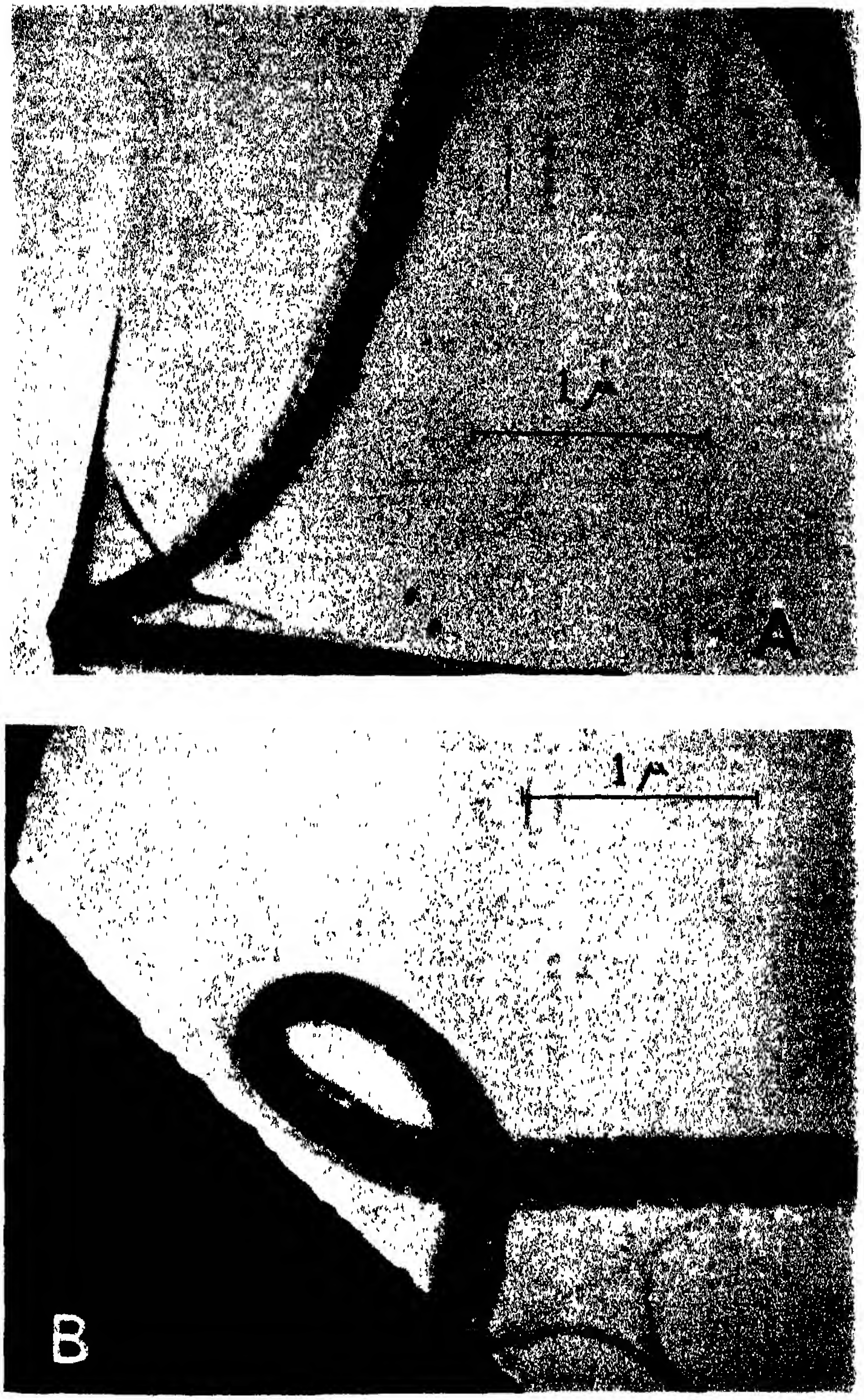


A. Portion of a diatom used for measurements and estimation of magnification EM 1703 D
B. *Astasia klebsii*. Portion of flagellum showing unilateral flimmer and indications of helix of sheath as in Plate 9 EM 1712 D. Technique #1.

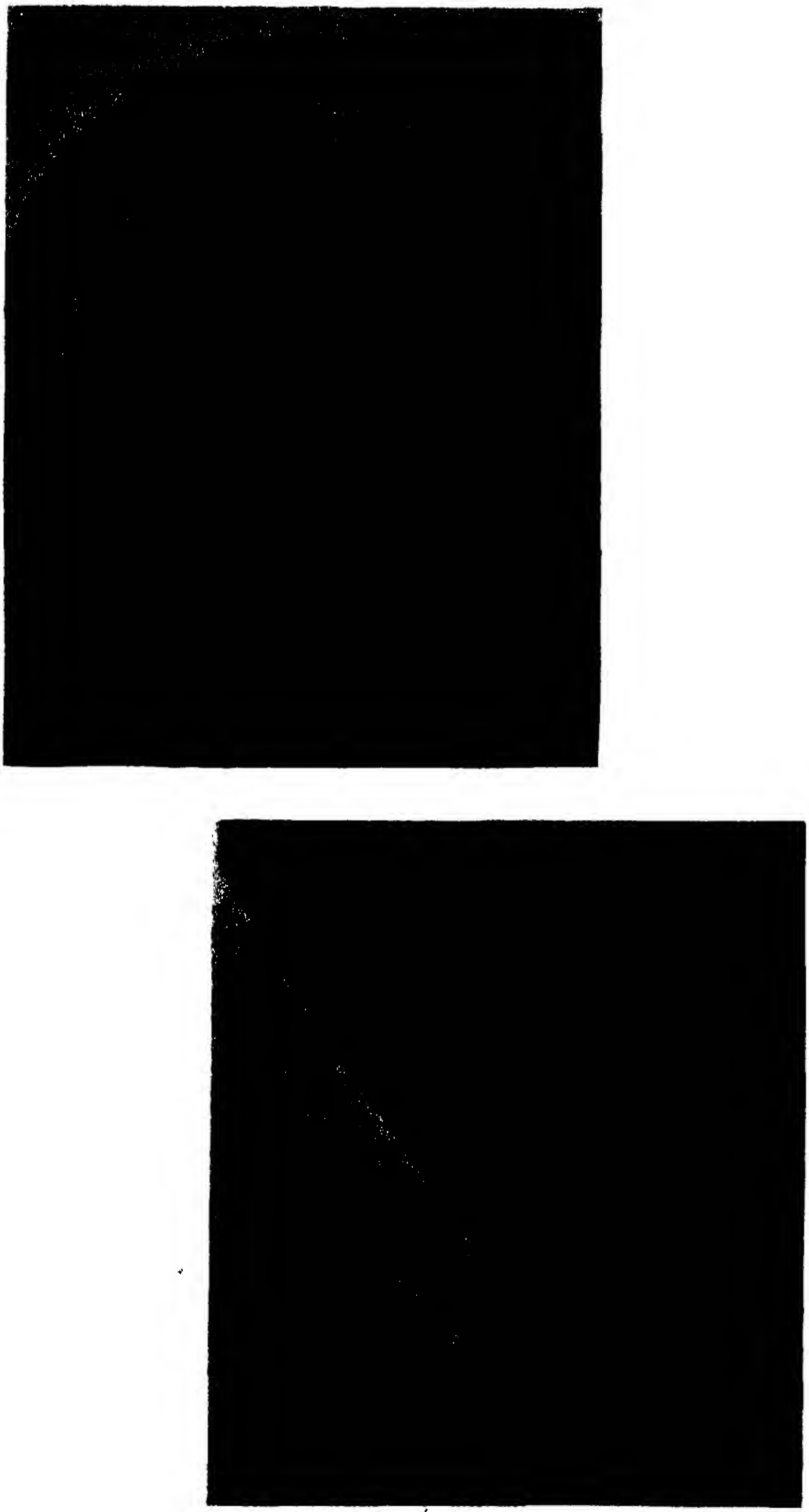




Euglena gracilis. Extremities of bodies and portions of flagella. Fig. A, EM 1704 D. Fig. B, EM 1096 D. Prepared according to technique #1.

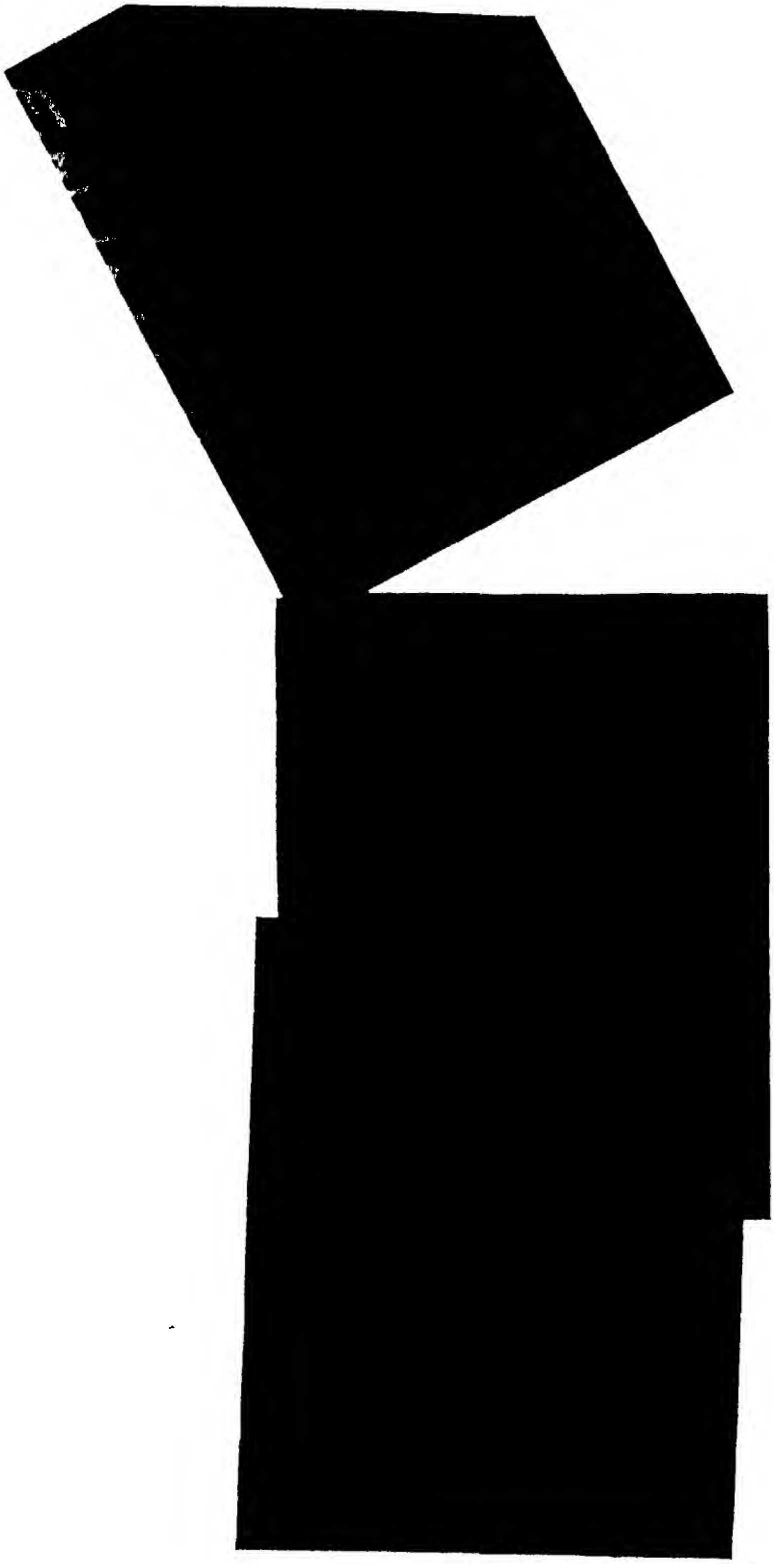


Euglena gracilis. Portions of flagella. In Fig A (EM 1691 D), the helical nature of the sheath is apparent Flimmer may be seen in Fig. B (EM 1687 D) Technique #1.

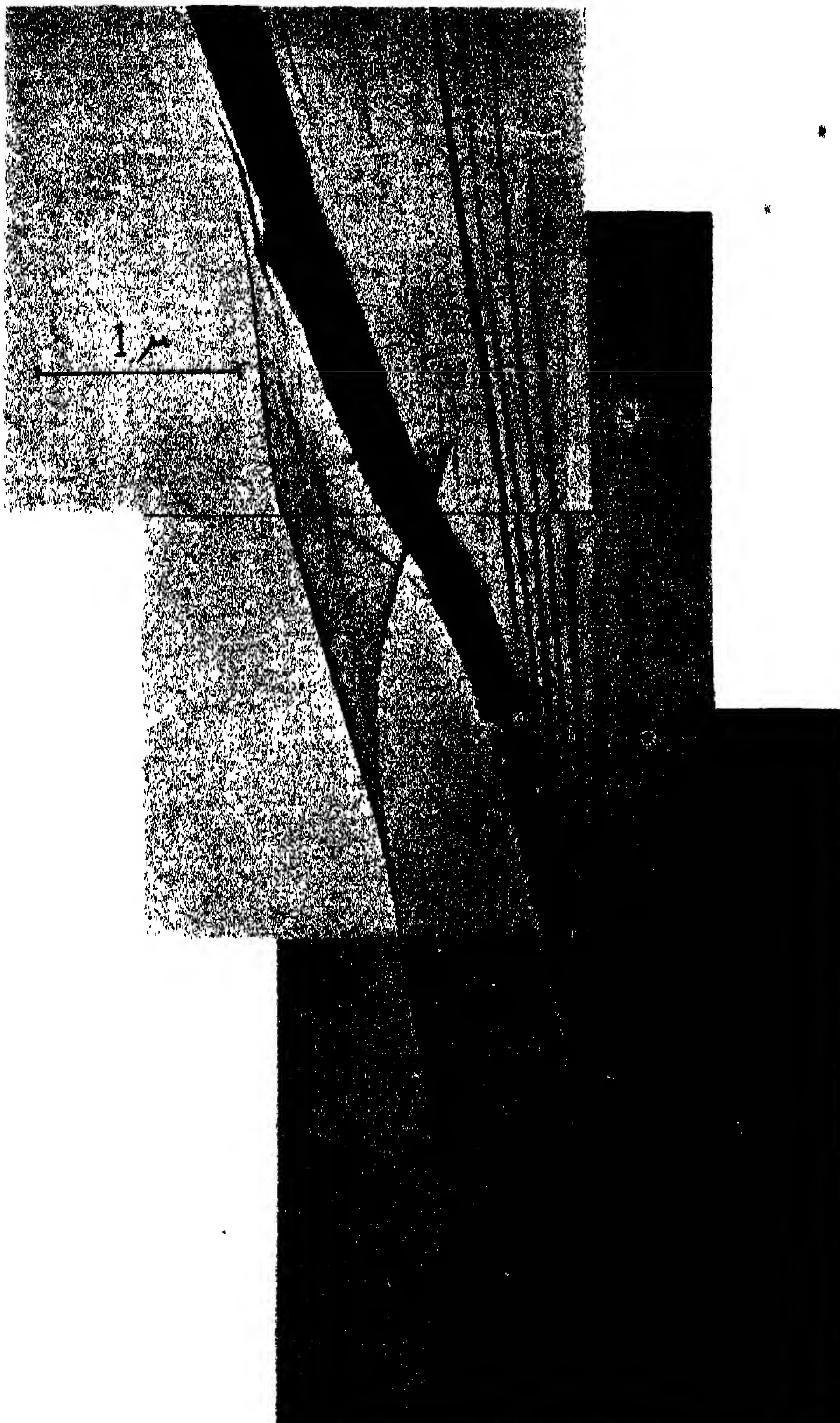


Euglena gracilis. Part of a flagellum showing unilateral flimmer especially well. EM 1700, 1701 D Technique #1.

Euglena gracilis. The flagellum extends from the body, loops, and returns to lie alongside the body. EM 1710, 1711 D Technique #1.

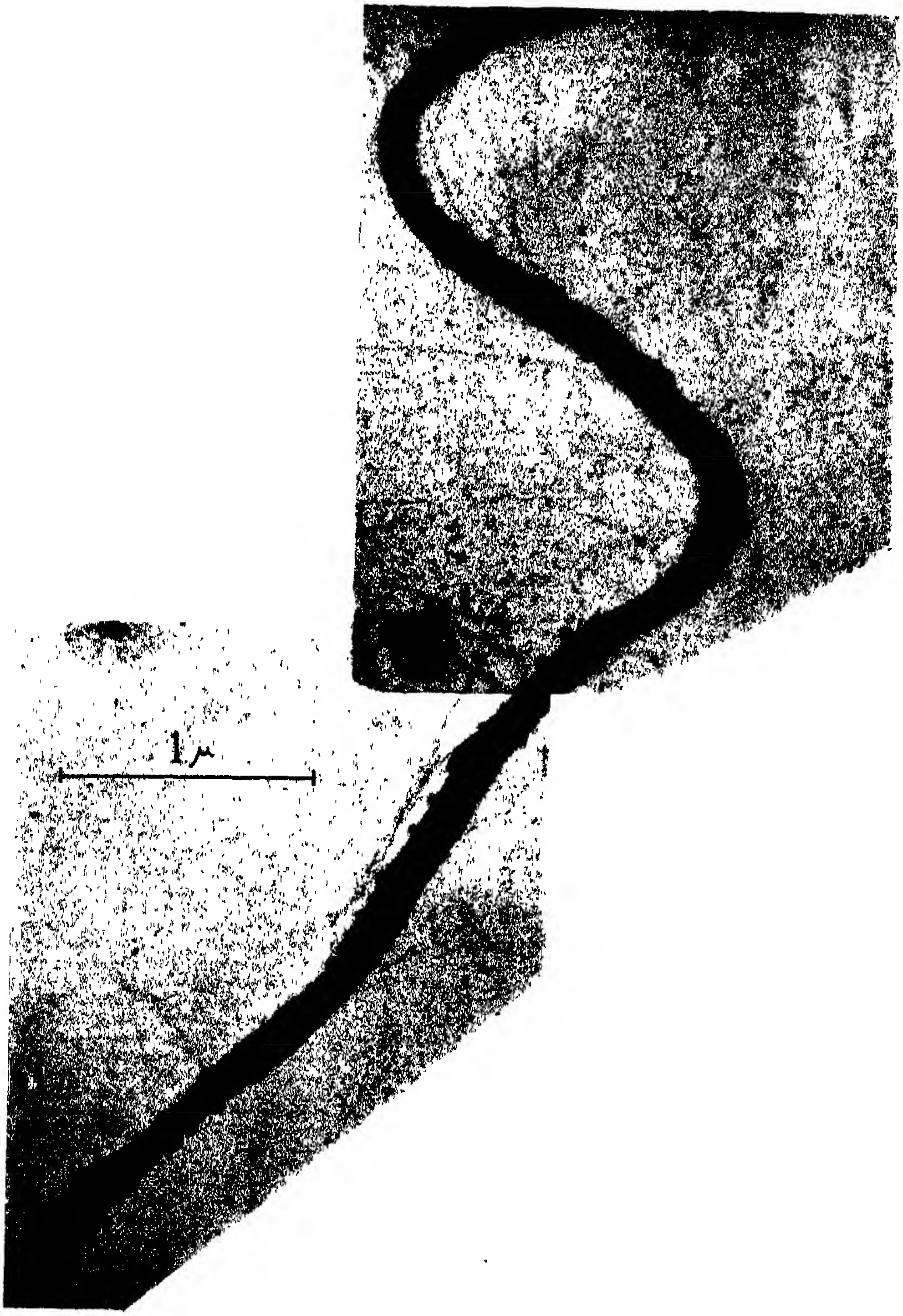


Euglena gracilis In the upper section, the flagellum is seen to emerge from the body. It has been snapped by a rupture of the supporting film, and parts of the axoneme are exposed. The length of the flagellum is about 13 μ. EM 1697, 1698, 1699 D. Technique #1.

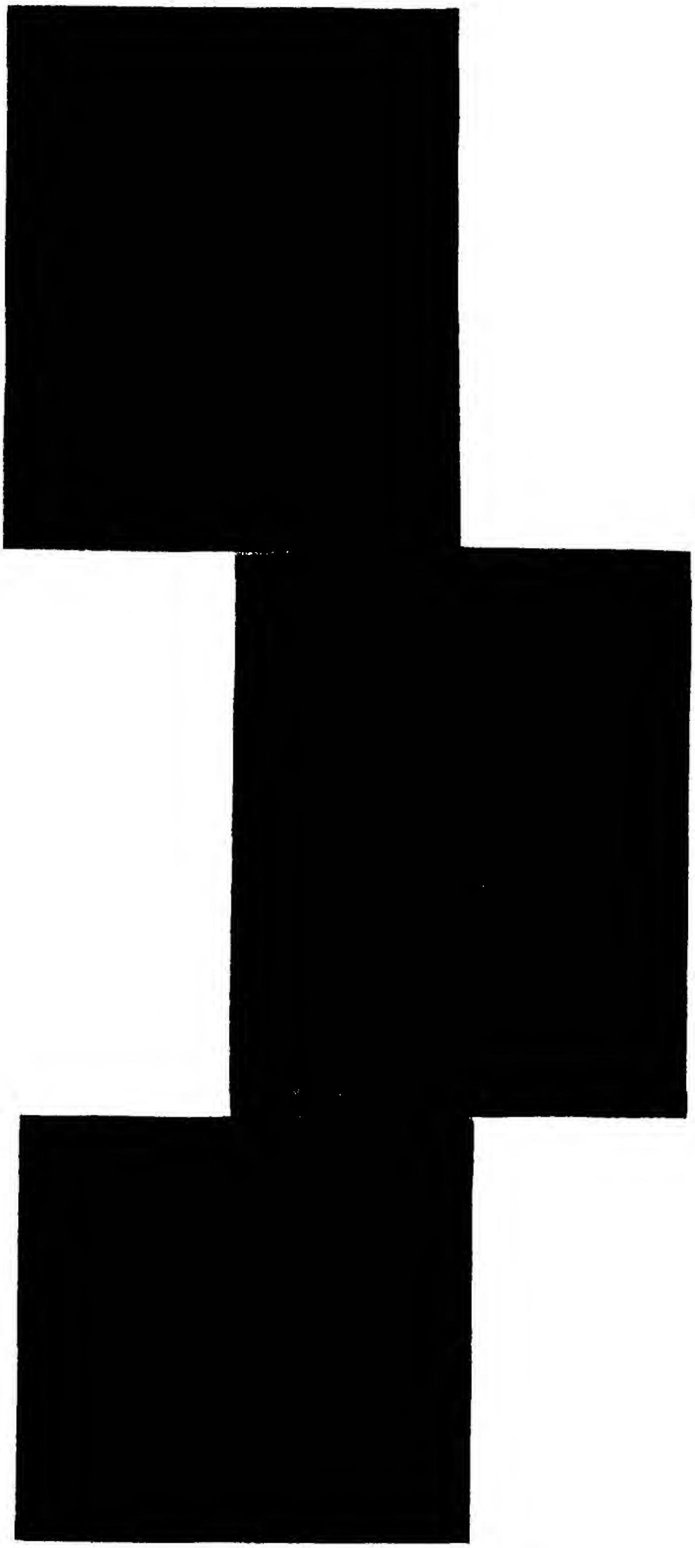


Euglena gracilis Portion of the flagellum showing two very different appearances. The upper part perhaps represents the more nearly natural condition See discussion in text. Note the transversely striated appearance of the upper, denser portion, produced by the closely wrapped helical fiber EM 1692, 1693, 1694 D. Technique #1.

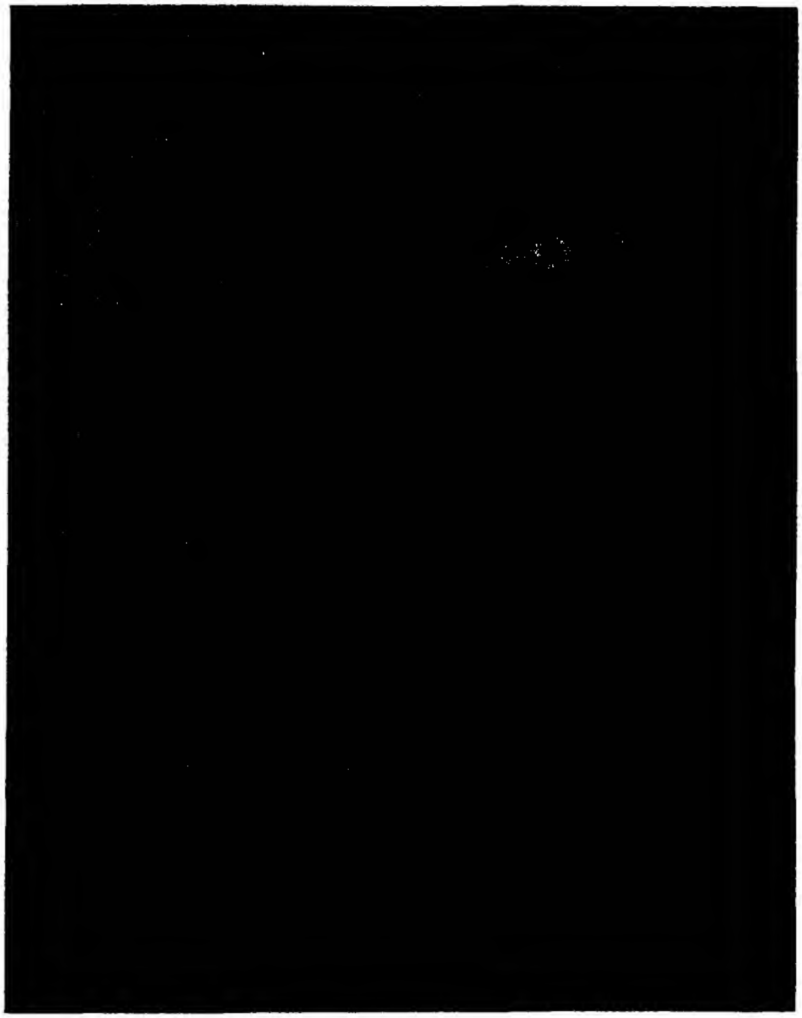
Euglena gracilis Portion of flagellum showing a swollen appearance, perhaps due to the escape of flagellar plasm during drying EM 1707, 1708 D Technique #1.



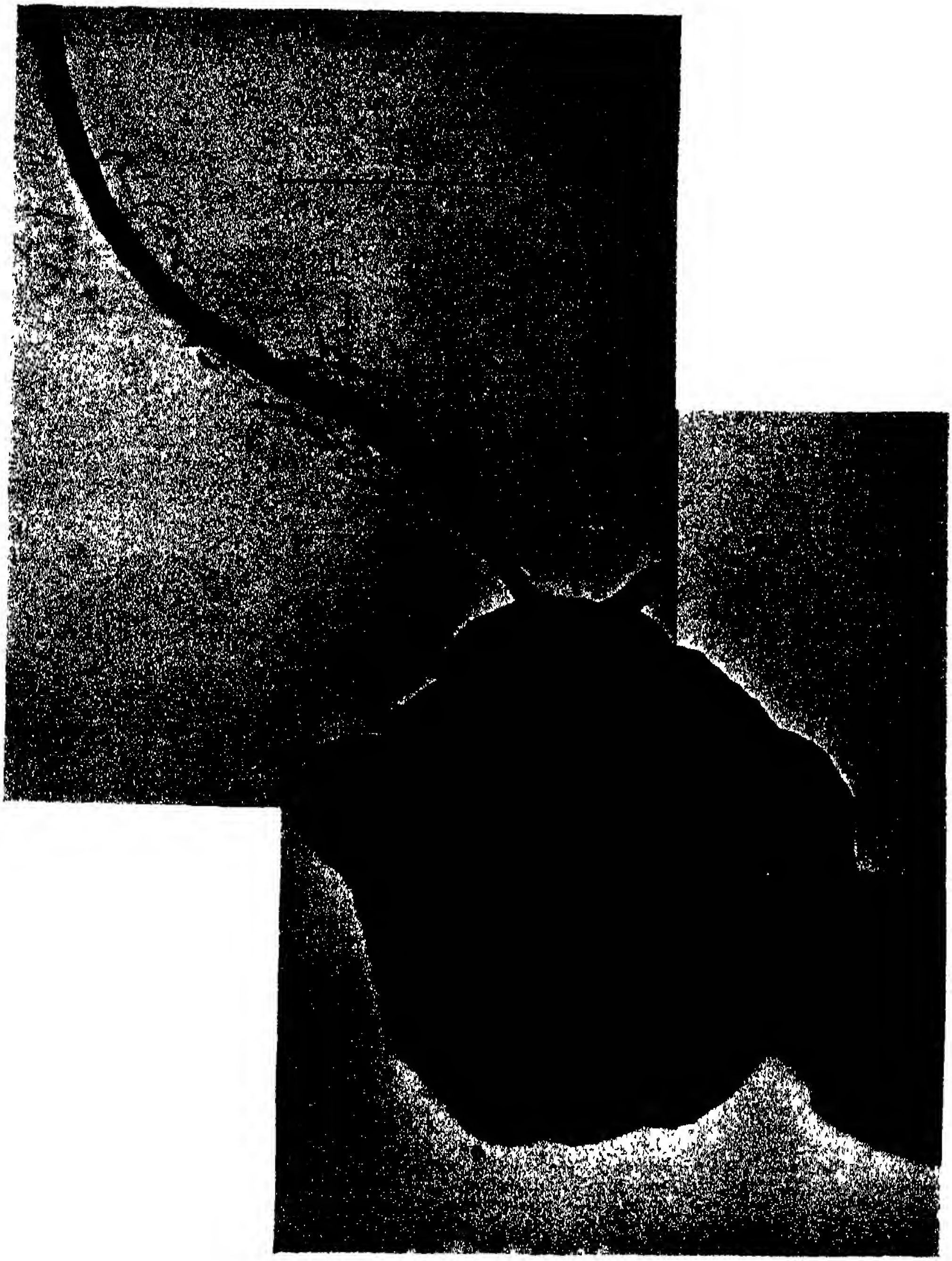
Euglena gracilis. Portion of flagellum showing unilateral flimmer. In places where the flagellum is twisted, the two equal fibers of the axoneme are made rather obvious. The helix of the sheath appears to be closely appressed to the axoneme (note regular bumps along sides of flagellum. EM 1620, 1621 D. Technique #2.



Chilomonas paramecium. Anterior end of body and the two flagella. No flimmer are to be observed. EM 1723, 1724, 1725 D. Technique #1



Ochromonas variabilis Portion of body and flagellum showing flimmer on both (all ?) sides, not in a single lateral row as on the flagellum of *Euglena*. The dimensions of *Ochromonas* flagella vary with the size of the organism, but in those photographed they ranged for the most part between 4 and 6 5 μ in length, averaging about 0 1 μ in diameter The flimmer seem to average about 0 5 μ in length and are less than 0 01 μ in diameter Note apparent helix as in Plates 9 and 1 B EM 1745 D Technique #1



Ochromonas variabilis. The entire body of the organism is shown, with most of the flagellum. The small second flagellum may be seen near the base of the long flagellum. No flimmer have been observed upon it Apparent helix as in Plate 11. EM 1737, 1739 D. Technique #1.

THE EYE-BANK FOR SIGHT RESTORATION

More than half a hundred hospitals in nine states are already cooperating with The Eye-Bank for Sight Restoration, Inc., in a nation-wide effort to help restore or remedy the vision of America's estimated 15,000 persons blinded because of corneal affections, it was announced recently by Mrs. Henry Breckenridge, executive director of the Eye Bank, 210 East 64th Street, New York.

In Greater New York alone, 32 hospitals are associated in the movement to make available for distribution healthy corneal tissue for those whose sight may be restored through corneal graft operations by which ocular opacity is overcome, the announcement stated.

In addition, 8 hospitals in other New York state cities, together with 6 in New Jersey, 3 in Connecticut and one each in six other states have become actively affiliated with the movement.

Organized only last February, the Eye Bank was established for the collection, preservation and distribution of healthy corneas which may be obtained only from persons either living or immediately after death. Inasmuch as corneas may be preserved and utilized for transplanting to the eyes of others for only 72 hours, speedy collection and distribution is essential as soon as they are obtained. Whenever cooperating hospitals have eyes available, the Red Cross Motor Corps rushes them to the Eye Bank for distribution to persons requiring the corneal graft operation.

In addition to extending this activity to hospitals throughout the United States, the Eye Bank is presently engaged in a nation-wide effort to obtain support for its work through solicitations for memberships and donations of eyes after death.

BOOK NOTICES

Indiana Climate

Isaiah Bowman in an address at one of the recent meetings has declared that "facts more valuable than all the gold of the Klondike lie hidden in the climatological records of the Weather Bureau." Whether or not it might be further remarked that an equally valuable set of climatic facts are overlooked or obscured by Weather Bureau methods of taking and recording data, does not detract at all from the vast store of climatic data Professor Stephen S. Visher has compiled and summarized from Weather Bureau records in a book titled "The Climate of Indiana."

That Professor Visher has sought out so much of the hidden value in the records is obvious at a glance. That he recognizes certain limitations of Weather Bureau records is clear through study of his work. The 27-chapter book contains 70 tables and almost 500 figures, 400 of which are maps of Indiana which emphasize various aspects of the state's climate. Moreover, these are not the conventional presentations of averages and extremes, but presentations of data that may be utilized by workers in biology, geography and other fields. That it is not simply calculation for calculation's sake may be judged from the following types of data which he has mapped: Days per decade during which temperature was continuously below 10°; percentages of Junes, July's, Augusts which have had less than 1½" of rain; times per 40 years that the crop-growing season was humid, moist sub-humid, dry; January, February, March, etc., 2-day rains of 2 inches or more per decade; normal date of beginning of corn planting; average number of days per year with maximum temperatures below 32°. These are only a few samples of many.

The thoroughness of Professor Visher's research cannot be told in little space but is suggested by the chapter titles. Chapter 1 is a general discussion of Indiana climate, and more or less of a summary of the next 15 chapters. These deal specifically and in meticulous detail with weather phenomena such as temperature—average, high and low; killing frosts; precipitation—normal and near normal, drouths, especially wet months and seasons, snowfall, rainfall intensity, hail and floods; humidity; sunshine and clouds; winds; thunderstorms, lightning, tornadoes. Contrasts of seasonal weather and seasonal weather types are discussed in two chapters.

In Chapters 19 to 24, climate is discussed with relation to physiography, crops, and health. One chapter is devoted to classifying Indiana climate. He recognizes 3 general divisions, the western, central and eastern thirds, each section being further subdivided into 3 or 4 divisions

north and south. One chapter is devoted to the climate of Bloomington and the final one is given over to comparative climatic data from 6 widely scattered stations.

The effects of climate on Indiana topography is an interesting summary, for climatic elements—wind, water and ice—have all played significant roles in the development of Indiana scenery. That the author is cognizant of the fact that the Weather Bureau methods and compilations obscure certain vital extremes in local areas is shown in his discussion of the effects of physiography on climate, although the treatment is brief and data fragmentary. His analysis of factors affecting crop plants is much more thorough and certainly more functional than most statements made by ecologists and weather bureau analysts themselves.

Professor Visher has obtained most of what is obtainable from Weather Bureau records for a region the size of Indiana. • To this reviewer's knowledge it is more than anyone else has ever done for an area of similar size.

It is unfortunate that such an excellent work necessarily had to be based on data compiled on the conventional static monthly basis. Otherwise, seasonal contrasts, wet periods, drouths and other periodic events might have been better emphasized and compared. For example, it is difficult to compare percipitation phenomena of 28-day Februaries with 31-day Marches. Wettest 30 days, or driest 30 days, on the basis of long records or for individual years, are seldom, if ever, limited to the period between the first and last day of a given month.

What Deam has done for Indiana flora, Visher has matched in his treatment of the climate of Indiana. To investigators in fields where climatology is an essential adjunct, this work will prove valuable reference—not only for its information, but for its presentation, selection and analysis of date.—*John N. Wolfe.*

The Climate of Indiana, by Stephen S. Visher. 511 pages, 492 figures and 81 tables. Indiana University, Bloomington, Indiana, 1945. $4.00.

Infrared and Raman Spectra

Infrared and Raman Spectra of Polatomic Molecules is the third in a series of books on atomic and molecular spectra by Professor Herzberg. The first concerns itself with atomic spectra alone, while the second on *Diatomic Molecules* is really Volume 1 of the series on molecular spectra. The present volume on Polyatomic Molecules deals with Infrared and Raman Spectra from the points of view of both theoretical treatment of molecular models and the interpretation of experimental data on these models. This book is indispensable to both the beginner and to the man doing independent research in the field of molecular structure. Professor Herzberg has combined an elementary treatment of the problem of the vibration and rotation of molecules with a more advanced point of view. The text material is illustrated with many cases taken from the literature on the subject. Throughout the book are a number of fine print sections which may interest only the specialist, and which may be omitted by the beginner without the loss of continuity. The principal value of the book to the specialist is that it contains at least a thumb nail treatment of most of the molecular types known and extensive tables of both experimental and calculated data. The tables and bibliography are very well cross-referenced, so that where the treatment is not complete the original papers may easily be found. Professor Herzberg has recalculated many constants to fit a more uniform terminology, similar to that used in his *Diatomic Molecules*. The Introduction contains a treatment of Group Theory which should be found useful to many who have no previous knowledge of the subject.

Chapter I gives a general introduction to the subject of Linear, Symmetrical Rotator, Spherical Rotator, and Asymmetrical Rotator molecules in which energy levels, formation of spectra and intensities, are discussed.

In Chapter II, Professor Herzberg deals with the general problem of vibrating systems of particles. Considerable space is devoted to symmetry types of the normal vibrations in a great many molecules. Applications to several specific models, notably, linear and non-linear XY_2, and pyramidal XY_3. The subject of anharmonicities, and isotope effect are also treated.

Chapter III considers the Vibrational Infrared and Haman Spectra from both a Classical and Quantum Mechanical point of view. Following this are specific applications to a great many well-known molecules—CO_2, CS_2, H_2O, C_2H_2, etc.

The problem of the interaction between rotation and vibration is treated in Chapter IV. Combination relations which lead to the calculation of some of the molecular constants are developed. Various models are considered separately with discussions of their band appearance.

Chapter V contains applications of much of the foregoing material to the calculation of thermodynamic quantities.

Infrared and Raman Spectra of Polyatomic Molecules, by Gerhard Herzberg. xiii+632 pp. Fig. 174. 1945. D. Van Nostrand Company, Inc., New York. $9.50.—*Alvin H. Neilsen.*

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THE OHIO JOURNAL OF SCIENCE

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THE PRODUCTION OF OSTEOMYELITIS IN RATS[1]

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Rodet (1) in 1884 was the first to produce, by the intravenous injection of staphylococci into young rabbits, the suppurative necrotic lesions of bone resembling those of hematogenous osteomyelitis in man. Since then, other workers have employed rabbits, with considerable success, for studies of this disease. The dog has also been used, (2, 3, 4), but the results have been somewhat less satisfactory. Since small laboratory animals offer special advantages for the study of osteomyelitis, it seemed desirable to investigate the production of this disease in a relatively cheap and available animal, the rat.

Several years ago, in this laboratory, Mr. Paul Prager was able to produce experimental osteomyelitis in the tibia of the white rat. His technique was to insert a piece of No. 50 white cotton thread into the bone marrow, and then inject into the area a culture of *Staphylococcus aureus*. This paper deals with further studies and technical modifications of Prager's method.

The organism used in these experiments was a strain of *Staphylococcus aureus* which had been isolated from a patient with chronic hematogenous osteomyelitis. It was maintained on blood agar slants and stored between growth periods for as long as 6 months without losing infectivity. All cultures used as inoculums were prepared by transferring organisms from a blood agar slant to 0.1% glucose proteose peptone broth (Difco), and incubating at 37 C. for 24 hours.

The rats employed in these experiments were of the Wistar strain. Preparatory to inoculation, the animals were anesthetized by the parenteral injection of nembutal (40 mg. per kg. of body weight). For producing trauma of the bone or local inoculation, the hair on the leg was clipped, the skin swabbed with iodine, and a 1-cm. incision made over the medial aspect of the proximal portion of the tibia. The periosteum was scraped from the tibia, and a hole 1 to 2 mm. in diameter was pierced with a small forceps or scissors through the compact layer into the bone marrow. Following inoculation, the skin was sutured with cotton thread. The skin incisions healed rapidly, as a rule.

A number of variations in procedures used for the production of osteomyelitis were made:

Method 1: Rats were inoculated by injecting 0.1 ml. of culture deep into the marrow cavity.

Method 2: A 2- to 3-cm. length of No. 50 white cotton thread, saturated with the broth culture, was inserted deep into the marrow. This was followed by the injection of 0.1 ml. of culture into the marrow.

Method 3: A wisp of cotton, soaked with the culture, was inserted into the bone with the aid of a small curved forceps. As in method number 2, this was followed by the injection of 0.1 ml. of the inoculum.

[1]A preliminary report of this investigation was presented at the East Lansing meeting of the Michigan Branch of the Society of American Bacteriologists, June 1, 1945.

Method 4: About 0.1 ml. of warm 1.5% agar gel was injected into the marrow cavity. A few minutes were allowed to elapse, after which 0.1 ml. of the culture was injected into the agar mass. Dochez (5) used agar to protect streptococci against the defenses of the horse in inoculations made for the purpose of producing antiserum.

Method 5: One-tenth ml. of a 10% suspension of gastric mucin,[2] sterilized by autoclaving, was injected into the tibial lesion. An injection of 0 1 ml. of the culture was then made.

Method 6. One-tenth ml. of xylene, followed by the same quantity of culture, was injected into the marrow cavity

Method 7· This was the same as method 6, except that cotton soaked in culture, as described in method 3, was inserted after the injection of the xylene, and before the injection of the culture

Method 8: One-tenth ml. of the inoculum was injected into one of the tail veins. No local trauma was made

Method 9: The rats were given an intravenous inoculation of culture as described above Within 30 minutes, an opening was made into the marrow of the tibia, but no local inoculation of culture was given.

Method 10: The animals received 0.1 ml. of the culture intravenously, as well as 0.1 ml locally into the marrow cavity of the tibia.

Method 11· Intravenous inoculation of culture was followed by the injection of 0.1 ml. of a 10% solution of sodium morrhuate[3] into the bone marrow.

Method 12. This procedure was similar to Method 11, except that the tibial lesion was treated with xylene prior to being injected with the culture.

Following inoculation, the rats were observed for 3 or 4 weeks, at which time they were anesthetized, the site of inoculation reopened, and observations made as to the presence of subcutaneous abscesses, pus, necrotic bone, and the size of the aperture in the bone. A culture was made from the center of the inoculated area, in 0.1% glucose proteose peptone broth. If growth occurred, the organisms were stained by Gram's method and examined. If the aperture of the bone lesion was 3 mm. or more in diameter, contained pus, and yielded gram-positive cocci on culture, a diagnosis of osteomyelitis was made. To verify this conclusion, sections of affected bones from 14 rats, judged to have osteomyelitis, were sent to the Department of Pathology, where the diagnosis was confirmed by microscopic examination.

The results of attempts to produce osteomyelitis by the various methods outlined above are summarized in Table I. The most successful method appeared to be that of placing a non-absorbable foreign body, such as cotton, saturated with a broth culture of *Staph. aureus*, in the bone marrow. This method produced osteomyelitis in 94% of 81 rats. The use of method number 2, i. e., the insertion of culture-soaked thread into the bone marrow, followed by injection of 0.1 ml. of the culture, produced osteomyelitis in 72% of 60 rats. The addition of an agent, such as xylene, known to inhibit the action of the leukocytes, at least during the first hours following inoculation, did not increase the incidence of bone lesions.

Results following the injection of staphylococci and agar into the bone marrow, in the hope that the agar would interfere with the defenses of the rat, were as satisfactory as those obtained when thread was used as a foreign body. Of thirteen rats so inoculated, 77% developed osteomyelitis. The injection of mucin or xylene along with the bacterial inoculum did not result in any significant increase in the incidence of the disease over that of the group of animals receiving culture

[2]Lot No. 49799, prepared by the Wilson Laboratories, Division of Wilson and Company, Incorporated, Chicago, Illinois.

[3]Lot No. 097-S, Burroughs Wellcome and Company, New York.

alone. Staphylococci injected into the bone marrow, with no foreign body, caused osteomyelitis in only 12.5% of 16 animals so inoculated.

The intravenous injection of staphylococci into rats, with or without trauma to the bone, did not produce the disease.

Since osteomyelitis in man has a tendency to occur more frequently in the young, it seemed advisable to determine the relationship of the age of rats to their susceptibility to experimentally induced osteomyelitis. Rats were divided into two age groups as determined by their weights, the young group averaging 50 grams each and the adult group approximately 250 grams. All were inoculated by method 3. The results are presented in Table II. It will be noted that 85% of fourteen 50-gram animals developed osteomyelitis, while 72% of 14 older rats developed the disease. The difference in incidence of infection is suggestive of a somewhat greater susceptibility of young rats in comparison with older animals.

TABLE I

THE RESULTS OF VARIOUS METHODS FOR THE PRODUCTION OF OSTEOMYELITIS IN THE TIBIA OF THE WHITE RAT

Method Number and Procedure*	Number of Animals	Percentage of Animals which Developed Osteomyelitis
1 *Staph.* culture injected into bone . .	16	12 5
2. *Staph.* and cotton thread in bone. .	60	72
3. *Staph.* and cotton wisp in bone. .	81	94
4. *Staph.* and agar in bone	13	77
5. *Staph.* and mucin in bone . . .	18	11
6. *Staph.* and xylene in bone	16	19
7. *Staph.*, cotton and xylene in bone	20	85
8. *Staph.* intravenously..	9	0
9. *Staph.* intravenously and tibial trauma	9	11
10. *Staph.* intravenously and in bone .	13	0
11. *Staph.* intravenously and sodium morrhuate in bone	25	20
12. *Staph.* intravenously and xylene in bone	11	27

*The several methods are described in detail in the text.

TABLE II

THE EFFECT OF THE AGE OF RATS ON THEIR SUSCEPTIBILITY TO OSTEOMYELITIS

Average Weight of Animals	Number Inoculated	Percentage which Developed Osteomyelitis
50 grams . .	14	85
250 grams. . ..	14	72

Since the course of osteomyelitis in man is variable, ranging from acute to chronic, the course of the disease in one group of rats was followed for an extended period. Thirty-five rats with osteomyelitis 25 days after inoculation were observed 50 to 65 days longer. Sixty-six per cent of these animals still had gross evidence of the disease, while the remainder had evidence of healed craters in the bone, from which bacteria could not be cultured.

SUMMARY

Several modifications of a method for the production of osteomyelitis in the tibia of the white rat have been evaluated. The insertion into the bone marrow of a cotton wisp impregnated with a broth culture of *Staph. aureus* was found to be the most satisfactory of the various procedures tested. Substitution of a piece of cotton thread or of agar, for the cotton wisp, resulted in a significant though somewhat lower incidence of osteomyelitis. Little success was attained when no foreign body was present. The use of such agents as mucin or xylene did not significantly change the incidence of infection from that obtained when culture alone was injected into the bone

The susceptibility of young rats appeared to be slightly greater than that of older animals.

The lesions persisted for as long as 75 to 90 days in 66% of 35 animals.

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(4) **Schemen, L., Lewin, P., Sideman, S.,** and **Janota, M.** 1943 Experimental osteomyelitis Am J. Surg. 60 . 371-380

(5) **Dochez, A. R.** 1925 Etiology of scarlet fever. Medicine 4 251-274.

A Book to Enjoy

This volume is the third in a series on mountains for which Professor Roderick Peattie is acting as editor. In this instance he has contributed a foreword telling of his early enjoyment of mountain climbing in southwestern Colorado near the mining camp of Curay. By a lucky turn of fate he met Dr. Atwood on this jaunt. "I learned far more from Wallace Atwood on that trip than I did in his classroom," Peattie says and thus sets the whole atmosphere of the book, namely, to take the reader out into the field in company with a distinguished teacher who can be the serious field worker and have fun camping also. The chapters are alternately camping and geology. Nine of the National Park areas are treated in one chapter. In another, spiced with miner's yarns, a number of the famous Western mining centers are covered. Indians, ranchmen, farmers, tourists, camp trails and saddle horses all enliven the human picture. The stories of volcanoes, of how mountains rise and are worn down, the nature of core rocks and other topics present the vast geological panorama in the remaining chapters. Illustrations are of two sorts Photographs and numerous handsome pen sketches by Eugene Kingman. This is just the book for a present to an enthusiastic traveler.—*A. E Waller.*

The Rocky Mountains. Wallace W. Atwood. The Vanguard Press, New York, 1945 pp 324. **$3.75.**

THE WILMINGTON REGION

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The Wilmington Region occupies the greater part of Clinton County in southwestern Ohio on the eastern margin of the Little Miami drainage basin (Fig. 1). This region is the area tributary to the town of Wilmington The region is approximately circular with a radius of some ten miles from its center, the city of Wilmington

The settlement pattern is irregular, with property lines running in various directions forming many different geometric designs No north-south or east-west property lines, roads, or village streets occur in the region served by Wilmington. This settlement pattern is characteristic of the entire area between the Scioto and Little Miami Rivers known as the Virginia Military Lands [1] The failure of Wilmington to square with the cardinal points of the compass is noteworthy since the city was platted on a rectangular pattern as the county seat in August, 1810

The historical occupancy of the region can be divided into four periods (1) the early period of settlement from 1804 to the formation of Clinton County in 1810, (2) from the establishment of the county to 1852, when Virginia relinquished all her remaining claims to the Federal Government[2] (3) the opening of remaining lands to all settlers, 1852-1880, a period of greatest growth, and (4) 1880 to the present, a period of decline in population

The terrain of the Wilmington Region varies from undulating to gently rolling. It lies within the till plains of the Central Lowland.[3] The area was covered by drift during the Illinoian, Early Wisconsin and Late Wisconsin glacial stages [4] The most conspicuous glacial features are the Cuba Moraine, terminal moraine of the early Wisconsin, and the Reesville Moraine (Fig 1), terminal moraine of the late Wisconsin, and the erratics. The Illinoian drift was covered by a thin layer of loess. The underlying bed rock is dolomite, limestone and shale of the late Ordovician and early Silurian ages The Niagara Formation of early Silurian is the only mineral deposit worked in the area.

The streams of the region are small, often irregular in flow. Most of the streams are tributary to the Little Miami River with the divide between the drainage basins of the Little Miami and the Scioto Rivers following the Reesville Moraine through the eastern part of the county.

The original vegetation at the time of settlement consisted of an oak-hickory hardwood forest with oak, hickory, beech and maple predominating.[5]

The soils are gray-brown podzolic and gray planosols [6] These soils have been formed in a humid, intermediate climate. The podzolic soils are the more fertile and are associated with the Wisconsin drift. The planosols have been formed from the loess deposits and are characterized by the level areas they occupy and the development of impervious hardpan layers at varying depths.

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[1] Peters, W. E , Ohio Lands and Their History, 3rd ed. Athens, 1930, p. 123.

[2] Ibid, p. 134.

[3] Fenneman, N. M., Physiography of Eastern United States. New York, 1938 p. 455

[4] Austin, G. M., Surface Geology of Clinton County, Ohio. Wilmington, 1930. p 7.

[5] Watson, S. A., Vegetation of Clinton County at Time of Settlement. Wilmington, 1927. Mimeographed.

[6] U. S. Dept. of Agric.—Yearbook of Agriculture, 1936. Soils and Men, Map—"Soil Associations of the United States "

This region has been classified as humid microthermal with adequate precipitation at all seasons.[7] On the average, January is the coldest month (30.3° F.) and July the warmest (75.8° F.). The yearly mean is 53.0° F., with an average growing season of 153 days. The average annual precipitation over a 28 year period

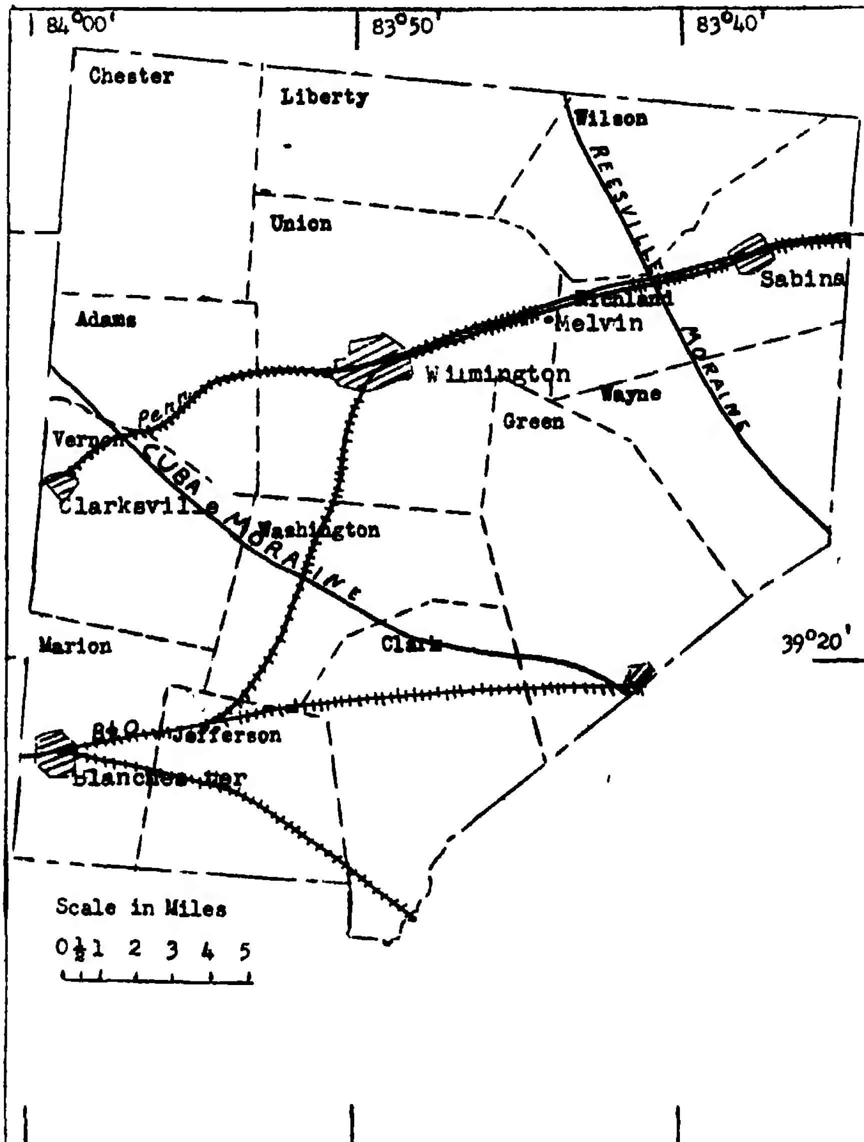

FIG. 1. Map of Clinton County, Ohio. Reesville Moraine—Terminal Moraine of Late Wisconsin Drainage divide between Little Miami and Scioto. Cuba Moraine—Terminal Moraine of Early Wisconsin. Wilmington—County Seat.

[7]Thornthwaite, C. W., "Climates of North America According to a New Classification," Geographical Review, Vol. 21, 1931, p. 633–655; p. 651; Map opposite p. 654.

is 45.9 inches,[8] rather evenly distributed throughout the year, but slightly higher and often irregular in the summer months.

ECONOMIC DEVELOPMENT

The difficulties of transportation in the early days of settlement made it necessary for the settlers to be practically self-sufficient. They raised all of their food and most of the products from which they made their clothing. Such early industry as developed was largely one of converting agricultural surpluses into marketable commodities, or to fill a local need Flour or grist mills, tanyards and distilleries were established to take care of an agricultural surplus. Brick, harness, shoe, hat, cabinet and wagon making were among the first non-agricultural industries of the community. These products were consumed locally[9] A corn-hog agricultural economy set in rather early. At first swine were driven to market, but by 1830 local slaughter and packing houses had been erected and shipments of their products were made by wagon to Cincinnati.[10]

The first railroad through Wilmington, the Pennsylvania,[11] was opened for traffic in 1853.[12] This made connections with Cincinnati and Zanesville. In 1883 another railroad, the Baltimore and Ohio,[13] provided connections with Cincinnati and Columbus[14] These lines provided good facilities for bringing in finished products and shipping local agricultural products of the region to more distant markets.

The greatest change in the period following the building of the railroad came in a shift in the type of manufacturing. Local manufacturing already mentioned gave way to better and more economical products from other regions However, an industry involving the manufacture of metal products developed in Wilmington. Although this new industry depended on raw materials imported from outside the region and upon a national market for the sale of finished products, it has attained great importance in the local economy.

The earliest highway in Clinton County was Kenton's Trace, known as the Urbana or Ripley Road, which was laid out before 1803.[15] The present system of roads is the outgrowth of various traces, turnpikes, toll roads and after 1848, free roads.[16] These early roads were poor by present standards, mostly rough, narrow, gravel roads, but none-the-less important.

The advent of the automobile changed road building standards here as elsewhere. Today Wilmington is the center of an excellent system of hard surfaced highways radiating throughout the county and providing easy access to all parts of the state. The importance of Wilmington to the county increased with the development of the automobile. The city became physically more accessible and in terms of time was now closer to all parts of the county. The Wimlington Region itself increased in size.

ECONOMY OF THE WILMINGTON REGION

The Wilmington Region is near the heart of a small section of the corn belt in southwestern Ohio called the "Fayette-Champaign Livestock phase of the Corn

[8]U. S. Weather Bureau, "Climatic Summary of the United States to 1930," Sec. 69. Southwestern Ohio, and Annual Reports, 1931–1943

[9]History of Clinton County. Beers and Co., 1888, Chicago p. 482 491.

[10]Ibid, p 790.

[11]Originally known as The Cincinnati, Wilmington and Zanesville Railroad

[12]Annual Report of the Commissioner of Railroads and Telegraphs, State of Ohio, Year ending June 30, 1870. p. 622.

[13]Originally known as The Columbus, Cincinnati and Midland Railroad

[14]Annual Report of the Commissioner of Railroads and Telegraphs, State of Ohio, Year ending June 30, 1884 p. 684.

[15]History of Clinton, op cit., p. 359

[16]Ibid., p. 363, 364.

Belt," while the southern limits are included in the "Maysville-West Union General Tobacco-Livestock Self-Sufficiency" province.[17]

Within this farming region there is a minimum of diversity. As one moves from the center towards the periphery few changes are noticeable The terrain to the south becomes more highly dissected, the soil is less productive and there is less emphasis upon corn. No change is noticed within the region to the north and east where there is a continuation of the livestock phase of the corn belt. This type of agricultural economy extends to the hill section of the Appalachian Plateau near the Scioto River on the east, and northward of a distance of over fifty miles.

Farming methods are more or less uniform. Crop rotation, generally on a three year basis, is the accepted practice. The order of succession is corn, small grain, pasture and return to corn. Corn is first in importance occupying over one-half of the land; wheat is second occupying one-third the acreage devoted to corn. Corn is grown as feed for swine and cattle, both of which are cash income crops. Wheat is grown for feed and for sale, but much the greater amount for sale Other crops are: oats, sweet corn, rye, buckwheat, barley, wheat mixture (for feed only), soy beans, tobacco, potatoes and other vegetables.

The production of swine is of greatest importance in the Wilmington Region. Over 150,000 head are raised annually. Dairy products, sheep, poultry and some feeder cattle are secondary

Most of the livestock moves from the Wilmington Region to Cincinnati, Dayton, Columbus and Washington Court House, while a little goes to more distant points. The weekly auction at Wilmington serves as a concentration point. Movement of livestock is about equally divided between the railroad and motor truck. All stock shipped to the Dayton market moves by truck.

The Clinton County Lamb and Fleece Improvement Association markets lambs and wool for members in Clinton County. The Clinton County Farm Bureau purchases wool in the county for shipment elsewhere.

The most important dairy product in the Wilmington Region is fresh milk. Two dairies supply the city of Wilmington. Four truck routes are operated throughout the county by dairies in Dayton, Cincinnati, Washington Court House and the condensing milk plant at Hillsboro.

Poultry products, eggs, chickens and turkeys, are sold to hucksters, regular customers in town or to local dealers. Most of those sold are shipped by the local dealers to Dayton and Cincinnati.

The total cash income realized by the farmers of the region in 1942 was approximately $8,000,000. That received from livestock products exceeded 90 per cent of this total. Swine lead with 63 per cent; dairy products were next with 12 per cent; poultry, 8 per cent; cattle, 4 per cent; and sheep, 3 per cent.[18]

While livestock provide the source of the farmer's cash income, the production of grain for feed is of basic importance. Among those grains, wheat serves not only for feed but as a direct cash crop. Its sale accounted for 6 per cent of the cash income in 1942.[19] Most of the grain moves through the elevators at Wilmington.

The only mineral of economic importance in the region is Niagara dolomite. This formation has been quarried at various locations in the county. At the present time one quarry is in operation, at Melvin, 7 miles east of Wilmington.

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[17]Map, Type of Farming Areas in the United States, Dept. of Agric., Bureau of Rural Economics, 1936.

[18]Morison, F. L., and Falconer, J. I. "Estimated Gross Cash Income to Ohio Farmers from Sale of Agricultural Products and from Agricultural Adjustment Agency Payments, by Counties, 1942." Dept. of Rural Economics, Mimeographed Bull. No. 171. O. S. U., 1943. p 8.

[19]Morison and Falconer, op. cit., p. 8.

Manufacturing in Wilmington shows no relation to the raw materials available. All of the manufacturing is in the metal industries, namely, the production of auger bits, furnaces, grey cast iron, and products made from this iron. Most of the raw materials used by the four plants come from a distance of over 50 miles and occasionally from as far as Pennsylvania and Alabama. The market is both state and national. This is the largest group of metal manufacturers in the eastern half of the Little Miami Valley. Their labor supply, about 500 employees, mostly men, is drawn from the region and within a radius of 20 miles.

The retail business of the town depends to a large extent upon the surrounding farming community. Certain types of industry are definitely related to the agricultural economy. Elevators, feed mills, agricultural implement stores, and hardware stores supply the needs of the farmers. The town itself, with a population of only 6,000, could not alone support these establishments.

Wilmington and the surrounding agricultural area are an integrated unit. The city depends upon the purchasing power of the farmer as does the farmer upon the city as his market and a place in which to purchase his needs

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Catalog of Illinois Algae

The advancement of knowledge of any group of living organisms is proportionate to the time and effort expended by individuals who collect, identify, describe and record their findings in such a manner that their colleagues may judge critically their own labors. Periodically, if these researches are to retain their intrinsic value, it becomes imperative that they be criticized in the light of new discoveries and integrated into a workable whole. Dr. Britton has accomplished this to a remarkable degree for the algae of Illinois.

The 962 entries are distributed through 178 genera and constitute, with the exception of fifty names whose validity or taxonomic position are inconsistent with modern algal interpretation, a review of all Illinois algae A detailed review and classification of the literature concerning the state provides a basic starting point for future taxonomic studies. Each species in the compendium is accompanied by detailed distribution data concerning the exact locality within the County, the collector and the date of collection; Such data will be of inestimable value to the Illinois Alogolgist and of only slightly less interest to his co-workers in other states.

—C. E. Taft

A Catalog of Illinois Algae, by Max E. Britton. Northwestern University Studies in the Biological Sciences and Medicine, No. 2. 1944 **$3.00.**

MYRMECOLOGICAL TECHNIQUE

I. The Use of Ether in Collecting Ants

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Some years ago while collecting with Professor Fred Hitchcock, physiologist at Ohio State University, a nest of *Camponotus caryae* Var. (?) the limb containing the nest was wrapped up in the ground cloth carried by collectors, brought back to the Put-in-Bay laboratory where it was opened up in an unoccupied room on a hard flat floor and the attempt was made to capture all of the ants for a careful count. The species of this group are so extremely active that it was difficult for the two of us with tweezers and vials of alcohol to keep many of the ants from escaping from off the cloth. Professor Hitchcock suggested, "Would it hurt the specimens to etherize them?" As ether was handy it was used on the nest. Immediately the operation changed from one of desperation to one of placid comfort as we picked up the sleeping ants. Ever since that time the writer has carried in his collecting bag at least a half pound of ether. Where collecting has been from an automobile or motor boat, among accessories is another half pound or pound of ether.

I wish to point out that our knowledge of many species of ants is extraordinarily imperfect because the collector too frequently picks a half dozen specimens out of the nest into a small vial of 70 per cent alcohol, then when he returns to the laboratory and checks his material carefully he finds that he would like a much greater series of that particular species. Too frequently the species runs from minute minores through a long series of sizes of mediae into a few very active majores. The temptation is always to collect the large ants which are usually brighter colored and more conspicuous. The other possibility comes up that the few majores may escape in active species before the tweezers can be gotten into action and the collector may even wind up with simply a small number of minores which in the hands of a taxonomist not widely familiar with the group, could easily be described as a new species. Probably in the literature on North American ants a number of such have been described on either majores alone or minores alone. In certain species we suspect the work of some of our most eminent myrmecologists especially European workers on American material. The museum material just does not agree with our own field experience with related species in the same group.

Ether involves a small expense which to the majority of students of ants can be charged back to laboratory funds. For those who have to pay for it out of their own personal funds I would suggest that the cheap, impure ether which, before the war could be purchased in almost any sporting goods store, be used instead of the medical grade which is found about scientific laboratories. This cheaper grade of ether is used by out-board motor boat enthusiasts who pour it into the gasoline tank in order to get the boat up into the level of dangerous speeds. All racing boats use it. It usually costs about half as much as medical ether and comes in cans of one pound each. A comfortable amount to carry is one-half pound which quantity can be transferred to a medical ether can from the larger can of crude ether.

Some provision has to be made in the bag that the ether is carried upright as it tends to flow past the best of corks if it lies on its side. A leak of ether in the bag could produce serious results when the collector lights a cigarette. It can burn the collector badly when it seeps on to areas of thin tender skin.

The use of ether is especially desirable in collecting timber ants which from their environment are all active, fast climbers. In the capture of these, as soon as an opening is suspected of containing an ant's nest, a few drops or a teaspoonful

of ether is poured about the opening and into it. This stops any sudden egress of ants while the opening is being enlarged. During the process of cutting into the nest more ether is applied as needed when pockets of ants are discovered which are not fully asleep. The chunks of wood or other material can then be transferred to the ground cloth where the entire nest is collected almost at one's leisure.

In the case of the forms of *Camponotus caryae* it is very essential that the collecting be done in the late summer or fall or any time from then until the flight in early spring, and that the collection from the nest contain all forms from the minute minores to the largest majores. We have nests in this group where we are positive we have collected all individuals during cool weather in late summer and have succeeded in such nests in finding only one or two giant majores among a total population of several hundred individuals. These majores are nearly the size of the queen and give an entirely different picture of the species than one in which the two or three giant majores have escaped. Such careful collecting of entire nests of *caryae* in Ohio during the last several years has given us an entirely different picture of the local species from that obtained before ether was used, when frequently nine-tenths of the individuals of a nest would escape during the collection. Thus the use of ether has eliminated two or three suppositions from the Ohio list.

We find ether equally valuable in collecting ground *Formica*. Here usually much more is required; when we find that we have the nest of an unusual ant, particularly in the difficult *rufa* group, we pour into the opening of the nest several tablespoonfuls of ether and then with a long handled shovel which we always carry, proceed to dig the nest to the bottom, carefully etherizing all new parts invaded, at least until we find the queen The soil from the nest can be shoveled onto the ground cloth (3 ft. square or more) and sorted very carefully The error in such collecting is then reduced to the field workers which do not arrive during the operation. These usually come in just often enough that they can be picked up individually especially if the collector knocks them into the dug pit where they have difficulty in scrambling out. In such nests the majores, if any, are usually in the top of the nest and otherwise would escape very rapidly, as in the case of *caryae*. In many nests the majores are rather few, and very active. Too frequently the minores are a foot or more beneath the surface and are only in the top of the nest by accident. We could cite various museum series of type material where apparently the collector merely used a hand trowel and collected a dozen or so specimens out of the top galleries. From what we know of related species there were probably minores of an entirely different size and color in the deeper layers of the nest. Etherization permits the collector to take his time and dig to the bottom of the nest or until he is sure he has all possible forms and enough material to pass specimens to other workers.

In various species during the pre-swarming period the males will be found about the nest opening or, in timber ants, frequently a foot or two above it, and may escape the collector because of their extremely nervous activity and their location high up instead of below the entrance.

In ants which inhabit acorns or snail shells we have available in the car or boat a basket of hospital urine sample bottles with appropriate round, tight corks—at least fifty such bottles. We usually have a student or other helper who carries in his pocket several of these bottles and who collects by placing any suspicious acorn with wormhole in a bottle which he corks tightly. He delivers the tightly corked bottle to the ground cloth where the acorn is removed from the bottle and is etherized through the hole before it is opened enough to determine whether it contains a nest or not. If it contains no ants it is discarded. If ants are seen it is replaced in the bottle and tightly corked and taken back to the laboratory for further study. In this manner instead of getting a few partial nests under one acorn tree we have found as many as a half dozen species of ants and are fairly certain that we have the entire nest in each case except for the field ants not at home

At the laboratory, knowing that we have ants in each bottle brought in, we put a few drops of ether in each bottle before examination and then empty the bottle onto the laboratory table.

Ether has had less usefulness in large nests and in nests so placed that it is difficult to explore them. In large nests the ether would have to be used by the quart to control the whole nest. I am thinking of the great mounds of raw dirt built by the tree ant, *Formica exsectoides* Forel, frequently called the Allegheny mound building ant. Under favorable conditions, particularly in groves of yellow poplar (*Liriodendron tulipifera* L.) whose branches harbor vast numbers of honey dew producing insects, the mounds will be over forty inches high and six to eight feet in diameter. Ether is of little value in such vast colonies. The other type of large nest is that made by various varieties of *Formica rufa* across southern Canada in the talus slopes of limestone slabs under the cliffs of the geologists' Niagra Formation. In such a nest both hands have to be used to turn a slab three inches thick and two to three feet in diameter. Before the ether contained can be picked up the ants have dived into the crevices between even larger stones. One is lucky to capture a few dozen out of hundreds in the top chamber under the covering slab. This is where we wonder how soon inventive genius will produce a pocket sized steam shovel. Only a strip miner has a technique that could open such a nest to the bottom. A third type where ether has little usefulness is in the large flat nest areas produced in Ohio south of the glaciated area by what we class as *Formica fusa subsericea* Say. These nests are areas of raw dirt frequently ten feet in diameter with dozens or even a hundred or so openings. What appears to be the same species builds similar nest areas along the sandy shores of Mackinac Straits, Mich. In these large nests the transporting powers of the collector do not fit the amount of ether needed nor does the staying powers of the ether fit the collecting speed of the forceps wielding ant student. So far only rough estimates on thoroughly etherized fractions of such a nest have to be used in population estimates.

Ether has lessened value in collecting very minute species where the nest is a series of thread sized galleries in substrate of a color almost matching that of the ant. I think of Stenamma, Brachymyrmex, Proceratium, Ponera and many species of Strumigenys. These are so small that they can escape detection when they are not moving. They are usually more easily collected when shovelled onto a cloth. Here they are so slow and nest numbers are so low that few escape. If in an acorn or well defined chamber in wood sometimes a drop or two of three helps hold them until collected. Leptothorax only slightly larger is so active that ether is usually needed, and the same for the very fast species of *Iridomyrmex*.

Our experience with ether is that it does not injure the ant. On Canadian trips we have opened up nests of rare forms of *rufa* and when we found that they were within a few days of the emergence of the winged brood from the cocoon, have thoroughly etherized the nest, picking out samples of the various castes available, and have closed the nest to come back two weeks later to find it as active and contented as if it had not experienced a fairly complete etherization. Probably ants that ether actually struck were killed, but care can be taken not to pour the ether directly on masses of ants. We used it also in such preflight broods brought into the laboratory for emergence. We cannot find that etherization injures either the workers brought along to care for the brood or the brood itself, providing that ether is not poured directly onto the living ants. This gives one complete control of living laboratory samples.

We might observe in closing that studying ants in the field is work and not a holiday or picnic. More and more rarely do we merely sample nests and only where we feel fairly certain that we can return within a few days. The ant sampler merely makes trouble for the taxonomist and the museum man. Science from its nature is thoughtful of others and cooperative in its better techniques.

THE MEXICAN SPECIES OF IDIODONUS (HOMOPTERA-CICADELLIDAE)

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The Genus Idiodonus was described by Ball[1] in 1936 to include several species of blunt headed North American leafhoppers. *Jassus kennicotti* Uhler was made the genotype. With few exceptions these are tree inhabiting forms. In Mexico they have been collected from trees and shrubs all the way from the low desert shrub vegetation near sea level to 12,000 feet elevation from evergreens in some of the higher mountain ranges. More species have been found at altitudes of 5,000 feet or more than at lower elevations.

Only a few species apparently live at low altitudes. *Schwartzi* has been taken in the low desert and up to 5,000 feet elevation. At 5,000 feet elevations several species are found, some of which, *vinculus*, *claustrus* and *copulus* for instance, have not been taken at higher elevations. Others such as *acus*, *wickhami*, *albocinctus*, *latidens* and *nigridens* are found all the way from 5,000 to 10,000 feet and some even higher. A group of species, such as *rubellus*, *spatulus*, and *bicinctus* have not been found at elevations lower than 7500 feet. *Apertus*, *diserus*, *goodi*, *incidus* and *incisurus* have been taken only at 8500 feet elevation or higher while *titulus*, *insculptus* and *edentulus* have not been taken at elevations of less than 10,000 feet. Many of the species of this group are definitely alpine in distribution.

Very little work has previously been done on the Mexican fauna and as a result 30 of the 35 species treated in this paper are described as new. The largest group of related species is the *belli* series. The *kennicotti* group is represented by a few species, such as *vinculus*, *spatulus*, *copulus* and *apertus*. *Latidens* and *bakeri* are species apparently closely related to *terminalis*.

Thamnotettix fasciaticollis Stål is a species which is apparently represented in this material, but since the description will apply to any one of several species, and I have no authentically identified material, I am not able to definitely place the name upon any one of the species of this group.

The genus *Colladonus* was also described by Ball at the same time as *Idiodonus*, and *Thamnotettix collaris* Ball designated as the genotype. No specimens of the *collaris-clitellarius* group have been found in Mexico and it is doubtful if these can be distinguished as a generic group.

While this is not a completed list of the Mexican species it does bring together all available material at this time which has been collected by Dr. Alphonse Dampf, Professor of Biology at the Escuela Nacional de Ciencias Biologicas located at Mexico City, D. F., and the material collected by Drs. C. C. Plummer, J. S. Caldwell, E. E. Good and the writer during two field expeditions in many ecological habitats and various areas of Mexico. The author desires to express his appreciation to all of these colleagues for assistance rendered in the field studies.[2]

The color pattern of the head, pronotum and scutellum, are quite distinct and uniform and have proven to be good characters for the separation of species. The last ventral segment of the female is also quite a good structural character for the distinguishing of species. The male characters in this group have not proved to be of significant taxonomic value.

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[1] Bulletin Brook. Ent. Soc. 31: 57, 1936.

[2] Since completing the manuscript new type material has been collected in Mexico (1945) by Stone, Plummer, Shaw, Balock, Elliott, Hershberger and the author. These type designations have been added to the appropriate descriptions.

The type material of all the species described in the following pages is in the private collection of the author.

KEY FOR SEPARATION OF SPECIES OR GROUPS BY COLOR PATTERNS

1. With black markings on apex or margin of vertex 3
   Without black spots or bands on vertex margin 2
2. Yellow, without any markings on vertex and pronotum .... **graeculus**
   With a row of fused spots just above margin .... **incisurus**
3. Vertex with black spots or a transverse band, often interrupted at middle between the anterior margins of eyes 6
   Vertex without black markings except on margin 4
4. Pronotum with a definite pale transverse band across middle or posterior half 5
   Without a pale transverse band on pronotum .... **schwartzi**
5. Pronotum with a broad transverse band on the posterior half .... **tubulus**
   Pronotum with a narrow band at middle, curved convexly forward .... **rubellus spatulatus**
6. Usually with an uninterrupted black transverse band between eyes 7
   Markings usually in the form of broken bands or spots 11
7. With conspicuous black spots, some of which are merged, on the entire anterior portion of pronotum .... **insculptus**
   Without spots, often with a black band on anterior portion of pronotum 8
8. With a definite conspicuous black band on anterior margin of pronotum 9
   With only traces of black markings on central anterior portion of pronotum .... **clathrus**
9. With a black band on anterior margin of pronotum only .... **mexicans goodi titulus claustrus**
   A band on posterior margin or disc as well as one on anterior margin 10
10. A distinct band on disc, not close to posterior margin .... **bicinctus**
    With a distinct band on posterior margin .... **pravus dampfi acus**
11. Black spots irregular and often quite small 13
    Black spots transverse often appearing as portions of broken transverse bands 12
12. Usually a pair of short transverse spots—not an interrupted band, **copulus diserus bakeri latidens plummeri**
    Appearing more as an interrupted band between eyes, **caldwelli wickhami albocinctus** and **verecundus**
13. Spots close to, usually touching eye 14
    Spots not touching eye 15
14. Spots rather small, narrow .... **vinculus beameri**
    Spots larger, irregular in form .... **incidus edentulus turpiter**
15. Spots just back of each ocellus rather large, rounded .... **anademus excavatus**
    Spots above ocelli quite small .... **apertus nigridens**

Idiodonus schwartzi (Ball.)

Thamnottix schwartzi (Ball) Canadian Entomologist 43: 197, 1911.

A broad headed species with margins almost parallel. Length female 5.5 mm.

Vertex broadly rounded, twice as wide between eyes at base as median length.

Color: Vertex white with red ocelli and a pair of small black spots on anterior margin about equidistant from each other and the eyes. A pale yellowish band extending between eyes across the basal portion. Pronotum dull gray tinted with yellow on anterior margin. Scutellum with the basal angles fulvous, median portion white, tinted with yellow. Elytra whitish subhyaline. Claval veins white. Veins on the disc brown. Face and beneath creamy.

Genitalia: Female last ventral segment with posterior margin produced and sinuate, slightly indented at center forming two broad slightly produced lobes either side of middle.

Specimens have been collected at Saltillo, Coah., Mexico, elevation 5000 ft., June 10, 1931 (M. F. 2058); Montemorelos, N. Leon, Mexico, elevation 1500 ft., June 3, 1930 (M. F. 2023) and Hacienda Fresno, Coah., Mexico, (M. B. 328) by Dr. A. Dampf. One specimen apparently belonging to this species was collected from desert shrubs north of Monterrey, N. Leon, elevation 1700 ft., September 22, 1941, by Good, Caldwell and DeLong.

Idiodonus apertus n. sp.

Resembling *schwartzi* in general form and appearance but with distinct color markings and female genitalia. Length 5 mm.

Vertex bluntly produced almost twice as broad between eyes at base as median length.

Color: Vertex white, ocelli orange, two round black proximal spots at apex and a small brownish spot behind each ocellus on disc. Pronotum dull brown, a conspicuous pale transverse band across the disc marked with scattered flecks of reddish pigment. Scutellum creamy white, basal angles fulvous. Elytra grayish, subhyaline, claval veins white. Veins on the corium dark. Face pale, sutures and faint markings of arcs brownish, beneath pale marked with brown. Ovipositor brown.

Genitalia: Female last ventral segment with the lateral margins rounded to a produced tooth either side of a deep, squarely excavated median third extending more than one-third the distance to the base and which bears a broad sunken median spatulate process extending almost to the posterior margin of the segment.

Holotype female collected at Puebla, Pue., Mexico, elevation 8500 ft., October 18, 1941, (K-78) by Plummer, Caldwell, Good and DeLong.

Idiodonus rubellus n. sp

Resembling *osborni* in general appearance but with different color markings Length 5.5 mm.

Vertex broadly rounded, almost parallel margined, more than twice as wide between eyes at base as median length.

Color: Vertex creamy white tinted with orange, ocelli red with a pair of rather small round black spots at apex. Vertex, pronotum and scutellum with numerous red flecks. Pronotum dull brown washed with yellow, with a narrow inconspicuous pale median transverse band Scutellum orange brown with a black impressed transverse median line, narrowly white margined on either side at middle. Elytra brown subhyaline. Veins and claval suture narrowly white. Veins on anterior portion of the wing inconspicuous. Face creamy, rather heavily flecked with red.

Genitalia: Female last ventral segment with the lateral angles produced, between which the posterior margin is deeply concavely excavated either side of a median rather broad spatulate process which does not extend to the lateral angles and is slightly notched at apex.

Holotype female collected at Mexico City, D. F., Mexico, elevation 7500 ft., September 1, 1939, by the author

Idiodonus vinculus n. sp.

Resembling *kennicotti* in form and general appearance but with different color markings. Length 6 mm.

Vertex broad and blunt only slightly produced, about two and one-third times as broad between eyes at base as median length.

Color: Vertex yellow with a pair of round black spots at apex In male there is a narrow brown transverse band between the anterior margins of the eyes. In female the ends of the band are marked with a black spot the central portion of which is reddish brown. Pronotum dark brown with a median white transverse band, and a narrow band along posterior margin. Scutellum reddish brown with a median transverse impressed black line, margins on posterior half, narrowly white. Elytra dark brown subhyaline, veins paler. Face yellow.

Genitalia: Female last ventral segment with produced lateral angles, between which the posterior margin is rather deeply excavated either side of a broad median produced tooth half the width of segment which is shallowly notched at apex. Male plates triangular, elongate, tapered from base to long pointed apices.

Holotype female collected at Jacala, Hgo., Mexico, elevation 5000 ft., September 26, 1941. Allotype male taken on Acapulco Road, Mexico, November 22, 1938. Both collected by Caldwell, Good and DeLong. Also paratype females collected at Mexico City, September 26, 1945, elevation 8500 ft. and at K-287 Jalapa Rd., October 14, 1945, elevation 7000 ft , by Shaw, Elliott, Hershberger and DeLong.

Idiodonus spatulatus n. sp.

Resembling *vinculus* in form and color but female with a spatulate last ventral segment. Length 5–6 mm.

Vertex broadly, roundedly produced, more than twice as wide between eyes at base as median length.

Color: Vertex yellow with minute red flecks, a pair of round black spots at apex. In the male there is a narrow interrupted transverse brown band between the anterior margins of the eyes. Pronotum brown, darker on posterior two-thirds, a narrow white transverse band across middle. Scutellum orange, a median impressed dark transverse line and margins of posterior portion white. Elytra dark brown, subhyaline, veins paler.

Genitalia: Female last ventral segment with produced angles, between which the posterior margin is angularly excavated almost halfway to the base either side of a broad spatulate median process, the apex of which does not extend to the lateral angles of segment. Male plates elongate, triangular, apices long, tapered.

Holotype female and allotype male collected at Mexico City, D. F., Mexico, elevation 7500 ft., September 1, 1939, from shrubs by Plummer and DeLong. Paratype females collected at Mexico City, September 26, 1945, elevation 8500 ft., by DeLong, Hershberger and Elliott.

Idiodonus copulus n. sp.

Resembling *kennicotti* in general form but with a narrower head and distinct coloration. Length, female 5.5 mm.

Vertex broadly rounded, almost parallel margined, more than twice as broad between the eyes as median length.

Color: Vertex white, ocelli red, two large round black proximal spots at apex, a triangular black spot just behind each ocellus, a broad orange brown transverse band between eyes at base. Pronotum dark brown with a median transverse white band. Scutellum, basal half orange brown. Median transverse impressed dark line from which a dark brown elongated spot extends to the margin either side of apex, posterior half white. Elytra smoky subhyaline. Veins of the clavus white. Veins anterior to the claval suture black. Face pale with black sutures and conspicuous dark brown arcs which fuse in a line either side of middle.

Genitalia: Female last ventral segment long, strongly, angularly produced from the lateral angles to form a pair of rather broad blunt teeth either side of a short V-shaped median notch.

Holotype female collected at Carapan, Mich., Mexico, elevation 5000 ft., (K-432) October 2, 1941, by Caldwell, Plummer, Good and DeLong. Paratype female taken at Taxco, Gro., Mexico, elevation 5700 ft., (M. F. 1554) December 23, 1929, by Dr. Dampf; and at K-287 Jalapa Rd., October 14, 1945, elevation 7000 ft., by Shaw, DeLong, Hershberger and Elliott.

Idiodonus caldwelli n. sp.

Resembling *apertus* in general form but with more produced head, distinct coloration and genital characters. Length 4.5 to 5.5 mm.

Vertex bluntly produced, almost twice as wide between eyes at base as median length.

Color: Vertex orange yellow with two round black spots at apex and a transverse dark brown band near base, interrupted at the middle, and with the portion next to the eyes curved posteriorly. Pronotum orange yellow with a narrow anterior black margin and the posterior discal portion brownish. Scutellum orange yellow with semi-circular black spots on the basal angles. Elytra smoky and subhyaline. Claval veins yellow, claval suture broadly orange yellow and the veins anterior to the claval suture black. Face yellow with sutures and remnants of several pairs of arcs, brown.

Genitalia: Female last ventral segment convexly rounded to form prominent blunt teeth between which there is a deep narrow rounded excavation either side of a broad median blunt spatulate process which does not extend quite to the posterior margin of the teeth on either side. Male plates triangular, convexly rounded to elongate pointed apices.

Holotype female collected at Jacala, Hgo., Mexico, elevation 5000 ft., September 26, 1941, by Caldwell, Good and DeLong. Allotype male from Oaxaca, Oax., Mexico, collected June 10, 1935 (M. F.-6196) by Dr. Dampf. Paratype males and females from Chilpancingo, Gro., Mexico, elevation 4500 ft., October 25, 1941; Iguala, Gro., Mexico, elevation 2800 ft., October 25, 1941; Puento de Ixtla, Mor., Mexico, October 21, 1941; Uruapan, Mich., Mexico, elevation 5000 ft., October 1, 1941; Tuxpan, Mich., Mexico, elevation 4000 ft., October 5, 1941; Zitacuaro, Mich.,

Mexico, elevation 6700 ft., September 29, 1941; Carapan, Mich., Mexico, elevation 5000 ft., September 30, 1941; Taxco, Gro., Mexico, elevation 5700 ft., October 26, 1941, and Cuernavaca, Mor., Mexico, elevation 4900 ft., September 8, 1939, collected by Plummer, Caldwell, Good and DeLong. I take pleasure in dedicating this species to Dr. J. S. Caldwell.

Idiodonus beameri Ball.

Idiodonus beameri Ball. Bull. Brooklyn Ent. Soc. 32 : 28, 1937.

A blunt headed species with an irregular row of black spots along vertex margin. Length 5.5 mm.

Vertex bluntly produced, almost parallel margined, twice as wide between eyes at base as median length.

Color: Vertex brown with a pair of large round proximal spots at apex. An elongated triangular black spot either side next ocellus which tapers to a point just above the apical spots. A quadrate spot just below ocellus between eye and ocellus another next each eye above ocellus. Pronotum dark brown. Scutellum yellow, basal angles brown, a heavy impressed brown cross on posterior half. Elytra brownish subhyaline, veins pale on clavus, dark brown on corium, costa broadly white. Face yellow.

Genitalia: Female last ventral segment almost truncate with a narrow V-shaped notch at middle reaching one-third the distance to base. Male plates elongate, roundingly narrowed to form long filamentous apices.

Specimens of this species were collected at Uruapan, Mich., Mexico, elevation 5500 ft., October 1, 1941; Carapan, Mich., Mexico, elevation 5000 ft., October 2, 1941; Puebla, Pue., Mexico, elevation 8500 ft., October 18, 1941; Zimapan, Hgo., Mexico, elevation 6000 ft., September 26, 1941; Zitacuaro, Mich., Mexico, elevation 6700 ft., October 5, 1941, and La Guarda, D. F., Mexico, elevation 9800 ft., October 26, 1941 All specimens were collected from pine by Plummer, Good, Caldwell and DeLong. In 1945 numerous specimens were collected at Deserto des Leones, D. F., in October; at Cruz Blanca, Vera, in October and at Rio Frio, D. F., in October by Shaw, DeLong, Hershberger and Elliott.

Idiodonus wickhami Ball.

Idiodonus wickhami Ball. Bull. Brooklyn Ent. Soc. 32 : 27, 1937.

A blunt headed species with red flecks on vertex, pronotum and elytra, with conspicuous black marks. Length 4 to 4.5 mm.

Vertex produced, bluntly angled, about twice as wide at base as median length.

Color quite variable. In well marked specimens the red flecks are conspicuous in the color pattern but may be entirely wanting. Vertex with a pair of elongated black spots at apex on margin, a median quadrate black spot just above these. A pair of black spots just beneath each ocellus and a rather narrow transverse black band just above ocelli between the anterior margins of the eyes which is slightly interrupted at the middle. Pronotum with a round, black spot behind each eye on anterior margin and irregular black mottling. Scutellum pale, with a pair of elongate median spots just back of pronotum, and a transverse black line on middle. Elytra pale, tinted with fuscus. Veins pale, often with rows of reddish flecks and darker pigment on veins. Face yellowish, heavily marked with broad dark arcs which are fused either side of median line and with black marginal sutures.

Genitalia: Female last ventral segment with the posterior margin convexly rounded from lateral margin and sinuate. Male plates elongate, triangular, concavely rounded to rather long acutely pointed apices.

This species is very common in the high altitude area and has been collected at Mt. Popo, Mexico, elevation 11500 ft., September 28, 1941; Mexico City, D. F., Mexico, elevation 7500 ft., September 1, 1939; September 16, 1923; La Guarda, D. F., Mexico, elevation 8500 ft., September 5, 1939; Chapingo, D. F., Mexico, elevation 9900 ft., March 31, 1924; Tlalpam, D. F., Mexico, September 16, 1923; Zitacuaro, Mich., Mexico, elevation 6700 ft., September 29, 1941; Carapan, Mich., Mexico, elevation 5000 ft., October 2, 1941; Toluca, D. F., Mexico, elevation 9700 ft., September 29, 1941; Puebla, Pue., Mexico, elevation 8500 ft., October 18, 1941; Rio Frio, D. F.,

Mexico, elevation 10300 ft., October 7, 1941; Zacapu, Mich., Mexico, elevation 6500 ft., October 4, 1941. Collected by A. Dampf, Caldwell, Plummer, Good and DeLong.

Idiodonus belli (Uhler)

Jassus belli Uhler. U. S. Geological and Geographical Survey of the Territories Bulletin, 3 : 471, 1877.

A blunt headed yellowish species with black markings. Length 5 mm.

Vertex bluntly angled, rounded at apex, almost twice as broad at base as median length.

Color: Yellow with black markings. Vertex with a pair of round black proximal spots on margin at apex. A transverse black band between the anterior portion of the eyes which is enlarged at each end next the eye. Pronotum yellow, the anterior margin broadly marked with black, a narrow black margin posteriorly. Scutellum yellow with a T-shaped black marking on the posterior half. Elytra subhyaline, veins bright yellow. Face yellow, with the sutures, antennal pits and portions of the arcs on the face black. Beneath, thorax black, abdomen yellow with a black ovipositor.

Genitalia: Female last ventral segment almost truncate with a short narrow median incision. Male plates rather short, convexly rounded to blunt apices. Pygofer extended the length of the plates beyond their apices.

This is the common species of this group found in the Rocky Mountain area of the United States, no specimens which agree with this species have been taken in Mexico.

Idiodonus claustrus n. sp.

Resembling *belli* in general appearance but with more produced head, distinct markings and genitalia. Length, female 4.5 mm.

Vertex produced, bluntly angled, less than twice as wide between eyes at base as median length.

Color: Vertex yellow with two large black spots at apex and a rather large spot beneath each ocellus, a broad black transverse band between the anterior portions of the eyes which is enlarged and curves basally at each end. Pronotum yellow, tinged with green, with a rather broad black anterior margin and some brownish markings on the disc. Scutellum yellow, black-margined anteriorly. A large T-shaped marking on the posterior half. Elytra black,. subhyaline. The veins broadly conspicuously marked with yellow. Face yellow, sutures black, faint traces of black arcs on either side.

Genitalia: Female last ventral segment with the lateral margins broadly rounding to posterior margin which is slightly concave with a median, short, rather narrow, semi-circular excavation which is broadly black margined. Male plates small, triangular, elongate with pointed apices.

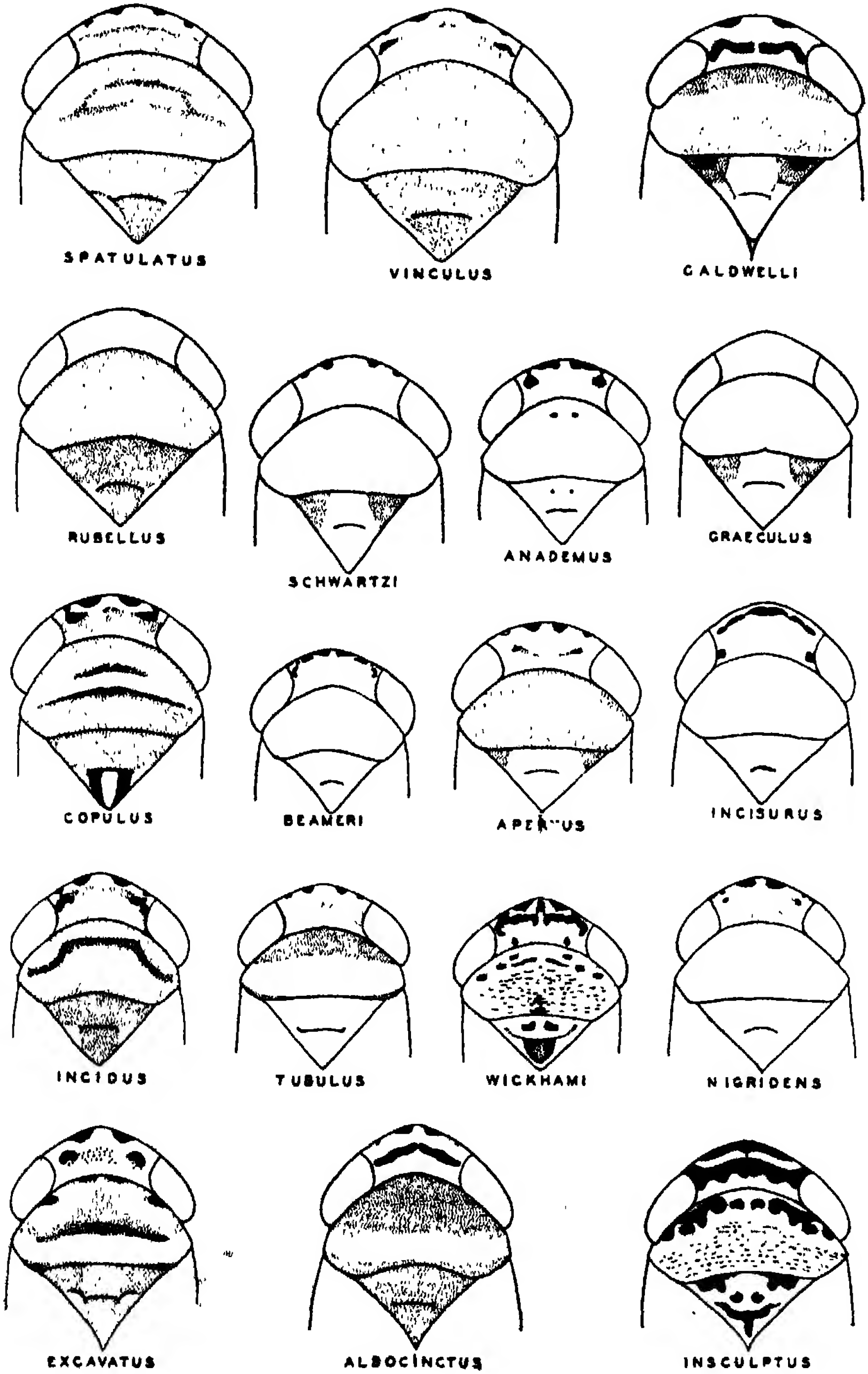
Holotype female collected at Orizaba, Ver., Mexico, elevation 4000 ft., October 17, 1941, by Plummer, Caldwell, Good and DeLong. Allotype male and paratype male collected at Las Cosca, Chiapas, Mexico, August 12, 1926, by Dr. Dampf. Paratype females were collected at Cruz Blanca, Vera., October 13, 1945, elevation 7000 ft., by Shaw, Hershberger, DeLong and Elliott.

Idiodonus bicinctus n. sp.

Resembling *belli* in general appearance and coloration but smaller and with different markings. Female 4 mm.

Vertex produced forming a blunt apex, about one-third broader at base than median length.

Color: Vertex yellow with a pair of large round black spots at apex and a minute black spot just beneath each ocellus. A broad black transverse band between the anterior margins of the eyes. Pronotum yellow with two black transverse bands, one is on the anterior margin of the pronotum, another on the posterior portion of the disc which does not extend to the lateral margins, giving the appearance of two black and two yellow bands. Scutellum yellow with a narrow basal black broken band and a rather conspicuous T-shaped black marking on the posterior portion. Elytra black subhyaline, veins conspicuously yellow except on costal and apical portion. Face yellowish with sutures and portions of arcs on face black.



Dorsal view of heads of species of Idiodonus showing the most conspicuous color markings.

Genitalia: Female last ventral segment with posterior margin bluntly, slightly concave, with a shallow narrow median notch. Median portion of segment black margined, giving the appearance of a deeper excavation.

Holotype female collected at Mexico City, D. F., Mexico, elevation 7500 ft., September 13, 1939, by the author. Paratype female, Mexico City, D. F., Mexico, June 12, 1924, collected by Dr. Dampf (M. B. 62).

Idiodonus dampfi n. sp.

Resembling *belli* in general appearance but with different color markings and distinct female genitalia. Length 4.5 mm.

Vertex blunt, almost twice as long at base as median length.

Color: Vertex creamy yellow, with a pair of large round black spots at apex and a smaller spot each side beneath the ocellus. A broad transverse black band between the anterior portions of the eyes, the posterior portion tinted with pale brown. Pronotum yellowish with a black band on anterior margin shading to brown on the disc and a narrow black band on the posterior margin. Scutellum pale brownish with a rather faint inconspicuous T-shaped mark on the posterior half. Smoky to blackish hyaline with pale veins. Face pale brownish, sutures conspicuously black, portions of dark arcs on upper half of face.

Genitalia: Female last ventral segment strongly produced forming a narrow conspicuous rounded tooth either side of a square shaped median excavation which is truncated at the base and black margined. Male plates broad at base gradually tapered to acutely pointed apices.

Holotype female collected at Cordoba, Vera Cruz, Mexico, elevation 3000 ft., November 19, 1930, by Dr A. Dampf (M. F. 1962). Allotype male collected at Bella Vista, Mexico, September 17, 1933, by Dr. Dampf (M. B. 366). Paratype males collected at Cosomatepec, Ver., Mexico, November 30, 1924, (M. B. 103) and at Chapingo, D. F., Mexico, elevation 9900 ft., November, 1924, by Dr. Dampf. I take pleasure in naming this species for Dr. Dampf who is interested in a thorough study of the Mexican fauna and has spent a great amount of time in the field collecting and studying insect material. Paratype females collected on the Morelia Rd. at the borders of Mexico and Michocan on September 28, 1945, elevation 9200 ft., by Plummer, DeLong, Hershberger and Elliott.

Idiodonus verecundus n. sp.

Resembling *belli* in general appearance and coloration but with a more angularly produced vertex and distinct female genitalia. Length 4.6 to 5 mm.

Vertex strongly produced and angled, one-third wider at base than median length.

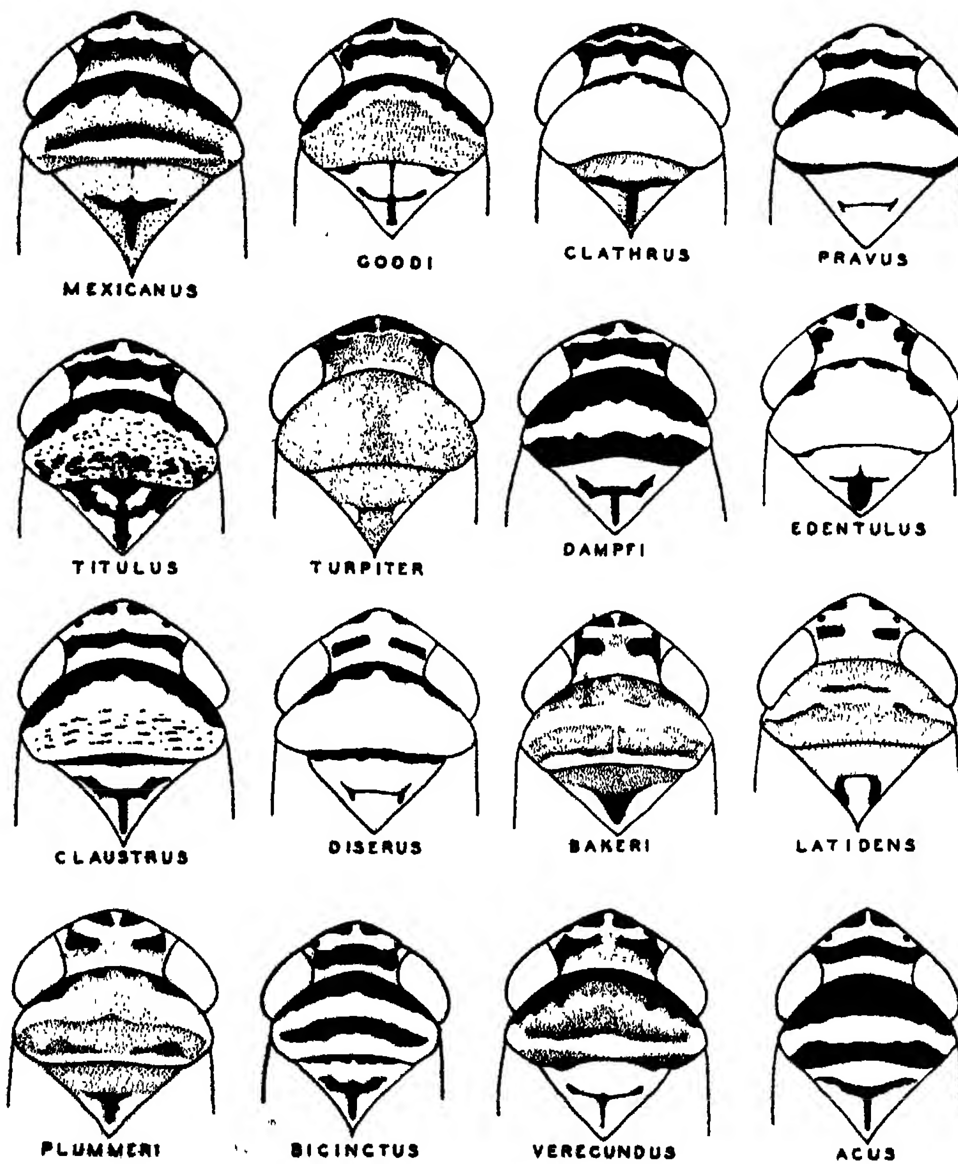
Color: Two large black spots at apex of vertex with a narrow pale portion between them. A rather conspicuous black spot beneath each ocellus, a rather broad black transverse spot each side between the anterior portions of the eyes which is narrowed on the disc and does not extend to the middle. Pronotum narrowly black margined anteriorly. Disc tinted with brown. Posterior margin dark brown forming a narrow pale band parallel to and not far distant from posterior margin. Scutellum pale brown with slight black markings on the basal angles, a T-shaped black mark on the posterior half. Elytra dark brown to black with pale veins. Face heavily marked with black or dark brown on sutures and arcs, beneath black or dark brown.

Genitalia: Female last ventral segment roundingly produced to median fifth which is shallowly, squarely, abruptly excavated about one-sixth the distance to the base.

Holotype female collected at La Guarda D. F., Mexico, elevation 9800 ft., October 26, 1941, (K-40), from pine by Good and DeLong. Allotype male and female paratypes collected from pine on the Morelia Rd. at the border between the states of Mexico and Michocan, September 28, 1945, by Plummer, Elliott, Hershberger and DeLong. Paratype male and females collected from pine at Rio Frio, D. F., October 18, 1945, elevation 9500 ft., by Hershberger, Elliott and DeLong.

Idiodonus acus n. sp.

Resembling *belli* in general coloration but with an angularly produced vertex and distinct genitalia. Length 4.5 to 5 mm.



Dorsal view of heads of species of Idiodonus showing the most conspicuous color markings.

Vertex angularly produced, about one-third wider between eyes at base than median length. Vertex distinctly pointed.

Color: Vertex white with a pair of large round black spots at apex. A rather broad, sinuate, black transverse band between the anterior margins of the eyes, posterior portion tinged with orange. Pronotum broadly black margined anteriorly, narrowly margined with black posteriorly, forming a broad transverse white band on posterior half which is bordered with orange anteriorly. Scutellum orange with a T-shaped black mark on the posterior half. Elytra smoky subhyaline, veins pale, costal margin appearing white. Face pale tinted with fuscous, with dark brown or black portions of arcs either side with sutures dark.

Genitalia: Female last ventral segment strongly produced from short lateral margins to a rather narrow rounded lobe either side of an excavation which bears a short round black tooth which does not extend to the posterior margin of the lobes. Male plates triangular, elongate with produced narrow apices.

Holotype female, allotype male and male and female paratypes collected at Rio Frio, D. F., Mexico, elevation 10300 ft., October 7 and 18, 1941; paratype male from Cuernavaca, Mor., Mexico, elevation 5000 ft., October 21, 1941. All material collected by Caldwell, Good, Plummer and DeLong. In 1945 paratype males and females were collected in forest areas of pine and fir from undergrowth at Deserto des Leones, D. F., on October 9 and 17 at elevations of 9500 ft., by Hershberger, DeLong and Elliott.

Idiodonus albocinctus n. sp.

A blunt headed species closely related to the *belli* group. Length 5.5 mm.

Vertex bluntly angled, less than twice as wide between eyes at base as median length.

Color: Vertex creamy white with a pair of large round black proximal spots at base. A very small black spot just beneath each ocellus. A transverse black band between the anterior margins of the eyes. This is slightly produced and sometimes interrupted at middle. Pronotum with a narrow black margin anteriorly, the anterior half and the posterior margin fulvous forming a rather broad pale transverse band across the posterior portion. Scutellum fulvous, a dark impressed transverse line across the middle. Elytra dark, smoky to black, with pale veins, face beneath creamy white with arcs and sutures dark.

Genitalia: Female last ventral segment strongly produced from lateral margins forming a rounded, rather narrow, produced lobe either side of a median broad shallow square excavation, almost truncate at apex and black margined. Male plates elongate, triangular, tapered to long acute tips.

Holotype female and allotype male collected at Deserto de los Leones, D. F., Mexico, elevation 9000 ft., July 11, 1924, (M. B.-72) by Dr. Dampf; Paratype males and females from Jacala, Hgo., Mexico, elevation 5000 ft., September 26, 1941; Carapan, Mich., Mexico, elevation 5000 ft., October 2, 1941, collected by Caldwell, Plummer, Good and DeLong. Paratype female from Chapingo, D. F., Mexico, elevation 9900 ft., June 11, 1924, (M. F.-196) by Dr. Dampf.

Idiodonus tubulus n. sp.

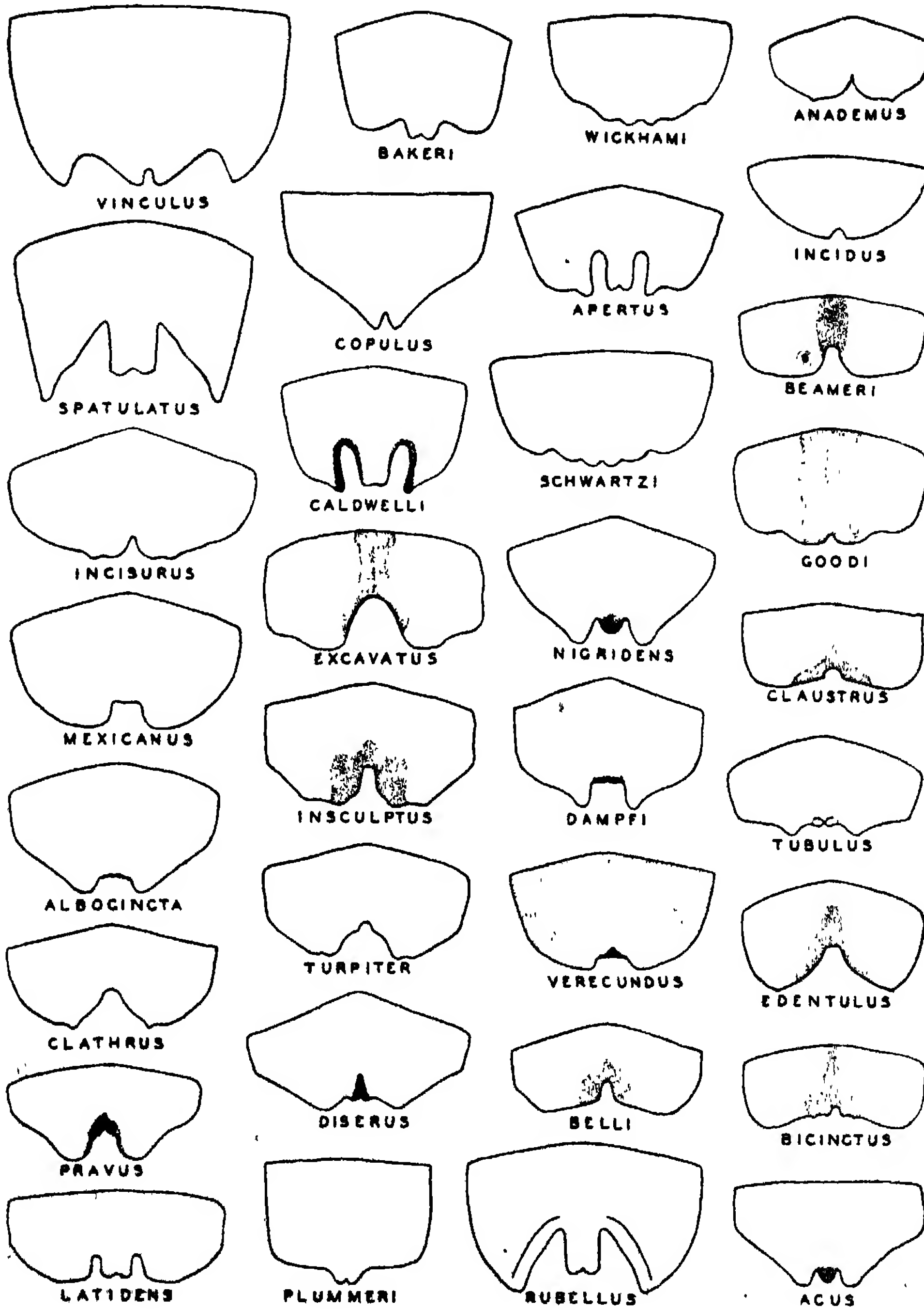
Resembling *albocinctus* in form and general appearance but without the black band on the vertex and with distinct female genitalia. Length 4.5 mm.

Vertex bluntly angled, twice as wide between eyes at base as median length.

Color: Vertex white with a pair of rather small dark brown spots at apex, the posterior half orange in the form of an irregular band between the eyes at base. Pronotum, anterior half pale brown, posterior portion white with a narrow, brown, posterior, marginal line. Scutellum pale brownish with a median transverse impressed dark line. Elytra pale brown subhyaline. Veins pale, face creamy tinted with fuscous, only faint traces of the arcs on either side.

Genitalia: Female last ventral segment rather short with posterior margins slightly produced to form a short blunt tooth either side of a broad shallow excavation which is slightly notched at the middle, forming what appears to be a pair of inconspicuous rounded sunken teeth. Male plates triangular, elongate, apices pointed.

Holotype female and paratype males and females collected at Chapingo, D. F., Mexico, elevation 9900 ft., November 25, 1924, by Dr. A. Dampf. Allotype male and male and female paratypes collected at Penon Marquez, D. F., Mexico, March 3, 1924, by Dr. Dampf.



Ventral view of last ventral segments of females of Mexican species of Idiodonus.

Idiodonus pravus n. sp.

Resembling *albocinctus* in form and general appearance but smaller and with distinct female genitalia. Length 4.5–5 mm.

Vertex bluntly angled, almost twice as wide between the eyes at base as median length.

Color: Vertex pale yellow with a pair of round black proximal spots at apex. A black spot beneath each ocellus. A rather narrow black band between the anterior margins of the eyes. Pronotum anteriorly and posteriorly margined with black; the anterior third dark brown; the posterior two-thirds yellow tinted with green. Scutellum fulvous with a median impressed transverse line. Elytra dark brown to black, veins pale, costal margin hyaline. Face yellowish tinted with brown, the sutures and portions of arcs brown.

Genitalia: Female last ventral segment concavely rounded from short lateral margins forming rather broad rounded lobes either side of a broad median excavation which extends more than one-third the distance to base and is broadly dark margined at the apex giving the appearance of a deeper notch.

Holotype female collected at Zitacuaro, Mich., Mexico, elevation 6700 ft., September 29, 1941. Paratype female from Carapan, Mich., Mexico, elevation 5000 ft., October 2, 1941. Both collected by Plummer, Caldwell, Good and DeLong.

Idiodonus diserus n. sp.

Resembling *albocinctus* in form and general appearance but with the transverse band replaced by a pair of transverse markings one on each side of vertex and with distinct female genitalia. Length 4.5 to 5 mm.

Vertex bluntly angled twice as long between eyes at base as median length.

Color: Vertex creamy white with a pair of rather large black spots at apex and a broad black dash either side of middle between eyes but not extending to eyes. Pronotum yellow tinged with green, a narrow black border both anteriorly and posteriorly. Scutellum yellow, bordered with black anteriorly with a median transverse impressed black mark. Elytra smoky, subhyaline with yellow veins. Face creamy white, sutures black, traces of brown arcs on each side of middle.

Genitalia: Female last ventral segment with lateral margins very short, posterior margins sloping to form a blunt lobe either side of a broad shallow excavation which is slightly notched at middle. The central apical portion heavily marked with brown, giving it the appearance of a deeper incision. Male plates triangular, rather broad at base with narrow pointed apices.

Holotype female collected at Chapingo, D. F., Mexico, elevation 9900 ft., June 18, 1929 (M. F. 210), male allotype and paratype males from the same locality collected March 17, 1924, by Dr. A. Dampf. Paratype male from Puebla, Pue., Mexico, elevation 8500 ft., October 18, 1941, collected by Plummer, Caldwell, Good and DeLong.

Idiodonus titulus n. sp.

Resembling *belli* in color pattern but a blunt headed, narrow, wedge-shaped species with distinct genitalia. Length 4.5 mm.

Vertex scarcely produced, broad, rounded, more than twice as wide between eyes at base as median length. Elytra long and narrow.

Color: Vertex bright yellow with two large round proximal spots at apex. A rather large, black spot just beneath each ocellus next the eye. A broad black band between the anterior portions of the eyes which is bent basally at each end. Pronotum dull brown, black margined anteriorly. Scutellum yellow with the basal angles, median basal spot and a T-shaped mark on the posterior half fused so as to form a heavy black marking, leaving only two yellow spots on the disc and the apical margin pale in color. Elytra black except the broad hyaline costal margin, veins yellow, face bright yellow without markings.

Genitalia: Male plates rather broad at base, convexly rounded to acutely pointed apices.

Holotype male collected at Mexico City, D. F., Mexico, 42 Kilometers south, at an elevation of 10,000 ft., September 5, 1939, by Plummer and DeLong. Allotype female and male paratypes collected at Cruz Blanca, Vera, October 13, 1945, elevation 7000 ft. Female paratypes were also collected at Deserto des Leones, D. F., October 17, 1945, elevation 9000 ft., and Rio Frio, D. F., October 18, 1945, elevation 9500 ft., by Shaw, DeLong, Hershberger and Elliott.

Idiodonus insculptus n. sp.

A broad blunt headed species with distinct dark marks on the anterior portion of the pronotum and scutellum. Length 6 mm.

Vertex broadly rounded, more than two and one-half times as broad as long.

Color: Vertex pale yellow with two elongated spots on margin extending between ocelli and fused so as to leave only a minute white spot at apex, the ends of the band extending beneath ocelli and fused with a spot below ocellus on each side. A broad black band touching the ocelli on each side extends transversely between anterior half of the eyes. This is sometimes interrupted at middle forming a black transverse spot at each eye. Pronotum yellowish, anteriorly, conspicuously marked with black spots, those along anterior margin are fused. The pair at the anterior center of the disc are rounded and are not fused with the other markings, posterior half marked with brownish pigment. Scutellum yellowish, anterior portion of basal angles marked with black spots. Two round black spots on the anterior portion of the disc and a heavy T-shaped mark on the posterior half. Elytra smoky subhyaline except the broad pale costal portion; veins yellow. Face pale yellow heavily marked with black, especially along the sutures, and black arcs of face which are fused on either side next to the clypeus and extend across the face just beneath the vertex.

Genitalia: Female last ventral segment with rather short lateral markings, the posterior margin sloping to a truncate position on median half which is rather deeply narrowly excavated. About one-third the distance to base the caudal margins are rounded to posterior margin. The excavation is broadly dark margined. Male plates triangular, elongate, apices pointed.

Holotype female, allotype male and male and female paratypes collected from pine at La Guarda, D. F., Mexico, (K. 40–43) at an elevation of more than 10,000 ft., September 5, 1939, and October 26, 1941, by Plummer, Good and DeLong.

Idiodonus edentulus n. sp.

A blunt narrow headed species with four conspicuous black spots on vertex. Length 5.5 mm.

Vertex bluntly produced and rounded, twice as broad between eyes at base as median length.

Color: Vertex pale yellow. Disk tinted with orange. A pair of large proximal quadrate black spots at apex. A black spot just beneath each ocellus. A minute brown spot at middle just above apical spots. A large quadrate black spot next each eye above ocellus with an elongated portion extending basally. Pronotum dull brown with a few black markings along the anterior margin. Scutellum yellowish with a modified T-shaped black spot on basal half. Elytra smoky, subhyaline, claval portion and costal margin paler. Veins pale yellow. Face yellow with portions of the arcs rather faint in color.

Genitalia: Female last ventral segment roundedly produced to posterior margin which is broadly, convexly rounded either side of a broad excavation which is narrowed and truncated at apex and extends about one-third the distance to base. Median half of the last ventral segment broadly dark margined.

Holotype female and paratype females collected at Rio Frio, D. F., Mexico, elevation 10300 ft., October 7, 1941, and September 22, 1941, respectively, by Plummer, Caldwell, Good and DeLong.

Idiodonus plummeri n. sp.

Resembling *caldwelli* in general form but with entirely different coloration and genitalia. Length 5 to 5.5 mm.

Vertex produced and bluntly angled, more than one-third wider between eyes at base than median length.

Color: Vertex creamy white with a pair of large black proximal spots at apex. These appear to almost fuse on their inner basal margins. A pair of elongate quadrate spots broadened next to the eye form the ends of an interrupted band between the anterior portions of the eyes. The central portion of the band is orange in color. The curvature of the posterior margins of the spots at apex and the anterior margins of the two quadrate spots give the appearance of portions of two concentric black rings. Pronotum dark brown with a median transverse white band.

The anterior margin is black and there are transverse black markings on the posterior half. Scutellum orange brown on anterior half, white on posterior half except for the triangular black mark on the median portion. Claval suture broadly white, claval veins pale, veins of the corium black, interrupted by white spots. Face creamy white with black sutures and black portions of arcs on either side.

Genitalia: Female last ventral segment rather long with posterior margin slightly produced to form a broad median tooth which is slightly notched at the middle.

Holotype female and paratype female collected at Rio Frio, D. F., Mexico, elevation 10300 ft., October 18, 1941, and September 22, 1941, respectively by Plummer, Good, Caldwell and DeLong. Paratype female from Tres Cumbres, D. F., Mexico, elevation 9100 ft., October 21, 1941 (K-52) collected by Good and DeLong.

Idiodonus latidens n. sp.

Resembling *plummeri* in general appearance but more narrow, with a more produced head, distinct coloration and genitalia. Length 5 mm.

Vertex angularly produced and bluntly pointed, about one-third wider between the eyes than median length.

Color: Vertex white with red flecks, with two round black spots at apex. A pair of short broad transverse spots between anterior portions of eyes. These are located next to each eye and extend about one-half way to the median line. Posterior portion of vertex washed with pale brown. Pronotum darker brown with a median transverse white band which is bordered irregularly with dark brown. Scutellum pale brown on anterior half. Posterior portion creamy yellow with a yellow transverse impressed line at the end of which the black spot extends to the margin either side of apices. Elytra brown, subhyaline, claval suture broadly white, costal margin broadly whitish hyaline, bordered posteriorly by a heavy brown line which extends from base to apex of elytron. Face pale, washed with pale brown, sutures black, traces of black arcs either side.

Genitalia: Female last ventral segment rather short, broadly rounded from lateral margin to posterior margin which is truncated on median half with a narrow excavation extending about one-fourth the distance to base either side of a broad median spatulate process which extends to about the posterior margin. Male plates rather long and narrow, triangular, concavely rounded to pointed apices.

Holotype female, allotype male and male and female paratypes collected at Zitacuaro, Mich., Mexico, elevation 6700 ft., September 29, 1941. Female paratypes from Mexico City, D. F., Mexico, elevation 7500 ft., September 1, 1939; Carapan, Mich., Mexico, elevation 5000 ft., October 2, 1941, were collected by Caldwell, Good, Plummer and DeLong. Paratype male from Chapultepec Hts., D. F., Mexico, elevation 8000 ft., Fenruary 16, 1926 (M. B. 150) collected by Dr. Dampf.

Idiodonus bakeri n. sp.

Resembling *plummeri* in coloration and general appearance but with a more angled vertex. Length 5 mm.

Vertex angled and bluntly pointed, about one-fourth wider between eyes at base than median length.

Color: Vertex white with a pair of large black spots at apex, sloping inwardly above and almost touching. A pair of elongate transverse spots, one just back of ocellus on either side extending one-half of the distance between eyes. The central interrupted portion of the band is a reddish brown color. Pronotum brown with a black spot behind each eye, a transverse band across middle and a marginal narrow band on posterior margin. Scutellum brown on anterior portion, a brownish triangular spot on middle of posterior half, white margined on each side. Elytra brown. Veins white on claval area, claval suture broadly white, costal margin white, veins of corium alternately marked with brown and white. Face white, sutures black, arcs of face either side black.

Genitalia: Female last ventral segment slightly excavated either side of a broad median tooth which is rather short and slightly notched at the middle.

Holotype female collected at Deserto de los Leones, D. F., Mexico, elevation 9200 ft., September 23, 1923, by Dr. A. Dampf. Paratype females from same locality December 9, 1923, and March 29, 1925 (M. B. 116) by Dr. Dampf. Paratype females collected at Deserto des Leones, October 17, 1945, elevation 9500 ft., by DeLong, Hershberger and Elliott; paratype female at Laguna de Zempoala, Mor., (K-10), elevation 8500 ft., by Plummer, Elliott, Hershberger and DeLong.

It is a pleasure to name this species in honor of Dr. A. C. Baker who has assisted the writer in so many ways in the collection and field studies of Mexican leafhoppers.

Idiodonus excavatus n. sp.

Resembling *edentulus* in general appearance but more robust and with definite coloration. Length 5.5 mm.

Vertex bluntly angled, almost twice as broad between eyes at base as median length.

Color: Vertex creamy white tinted with yellow with two round black spots at apex, a smaller semicircular spot convexly rounded anteriorly next each eye, between which is a reddish brown band. Pronotum brown on anterior half. Anterior margin narrowly black. A broad, white, transverse band extends across pronotum just before the posterior brown bordered margin. Scutellum yellow, basal angles orange, a median transverse impressed black line. Elytra pale brown, subhyaline. Veins white, claval suture broadly white, costal margin broadly white, subhyaline. Face yellow, sutures black, a round black spot beneath each ocellus and sutures of the face either side black.

Genitalia: Female last ventral segment with the posterior margin slightly produced forming a broad rounded lobe either side of a broad U-shaped median excavation, extending almost half the distance to the base.

Holotype female and paratype female collected at Zimapan, Hgo., Mexico, elevation 6000 ft, September 26, 1941, by Good, Caldwell and DeLong. Paratype females collected at Rio Frio, D. F., October 10, 1945, elevation 9500 ft., by Hershberger, Elliott and DeLong

Idiodonus mexicanus n. sp.

Resembling *excavatus* in general appearance but with a blunter vertex and distinct coloration. Length 4.5 mm.

Vertex blunt, about one and one-half times as broad between the eyes at base as median length.

Color: Vertex creamy white with two large round black proximal spots at apex and a rather large spot beneath each ocellus next the eye. A broad, irregular, black, transverse band between the middle of eyes. Pronotum brown, anterior margin broadly black with a rather narrow pale band, bordered anteriorly with brown, just before posterior margin. Scutellum orange brown with a conspicuous T-shaped black mark on the posterior half. Elytra dark brown to black subhyaline, costal area broadly white; veins pale.

Genitalia: Female last ventral segment with short lateral margins, posterior margin broadly convexly rounded forming a rather square excavated notch with a truncated apex one-fourth the distance to base.

Holotype female collected at Deserto de los Leones, D. F., Mexico, elevation 9200 ft, September 23, 1923, by Dr. A. Dampf.

Idiodonus goodi n. sp.

In general appearance resembling *mexicanus* but more narrow with a definite color pattern and distinct genitalia. Length 5 mm.

Vertex scarcely produced, almost parallel margined, almost twice as broad between eyes as median length.

Color: Vertex pale yellow with a pair of round black proximal spots at apex. A smaller spot just beneath each ocellus next the eye, a conspicuous transverse black band enlarged at either end between the anterior margins of the eyes. Pronotum dull grey, black margined anteriorly. Scutellum yellow, a semicircular dark spot in each basal angle, a black cross on the middle.

Elytra grey to smoky, subhyaline, veins pale. Claval veins broadly yellow, costal margin broadly pale, bordered posteriorly by broad brown stripe. Face bright yellow, unmarked.

Genitalia: Female last ventral segment with posterior margin sinuate, forming a broad rounded lobe either side of shallow median notch.

Holotype and paratype females collected at La Guarda, D. F., Mexico, elevation 8500 ft., October 26, 1921, and September 5, 1939, respectively, by Good, Plummer and DeLong.

I take pleasure in naming this species in honor of E. E. Good, whose excellent field work has showed him to be a promising biologist.

Idiodonus clathrus n. sp.

Resembling *insculptus* in general color pattern of the head but more narrow and without markings on the pronotum and with distinct female genitalia. Length 5 mm.

Vertex transverse and almost parallel margined, twice as wide between eyes at base as median length. Scarcely produced.

Color: Vertex creamy white, a pair of elongate transverse spots almost fused at middle, forming a broken transverse band on margin between ocelli. A black spot just beneath ocellus against each eye. A broad irregular band between the anterior portions of the eyes, almost paralleling the broken band on the margin. Pronotum dark brown mottled with black. Scutellum, anterior portion orange brown with a black T-shaped mark on posterior half. Posterior portion white. Elytra smoky subhyaline. Veins mostly brown. Face yellow, sutures black, black arcs on either side.

Genitalia: Female last ventral segment with posterior margin broadly rounded either side of a broad median excavation which is narrowed at apex and extends about one-third the distance to the base. Male plates elongate, triangular. Apices attenuated, long and slender.

Holotype female, allotype male and male paratypes collected at La Guarda, D. F., Mexico, elevation 9800 ft., September 5, 1939, by Plummer and DeLong. Paratype males and females collected at Rio Frio, D. F., Mexico, elevation 10300 ft., October 7, 1941, September 22, 1941, Mt. Popo, Mexico, elevation 11500 ft., September 28, 1941, La Guarda, D. F., Mexico, elevation 8500 ft., October 28, 1941, by Plummer, Caldwell, Good and DeLong. Paratype males and females collected at Rio Frio, October 18, 1945, elevation 9000 ft.; Morelia Rd., at border of Mexico and Michocan, September 28, 1945, elevation 7200 ft., and at Laguna de Zempoala, Mor., October 21, 1945, elevation 9500 ft., by Plummer, Elliott, Hershberger and DeLong.

Idiodonus turpiter n. sp.

Resembling *clathrus* in general form and appearance but with different color markings. Length 5 mm.

Vertex bluntly roundedly produced, twice as wide between the eyes at base as median length.

Color: Vertex white with a pair of transverse spots on margin between the ocelli. These are narrowest at the ocelli and are broadened at median line where they are narrowly separated with white. There is a small black spot beneath ocellus either side. There is a large black somewhat quadrate spot just above each ocellus which replaces the band in *clathrus*. The disc is broadly orange brown. Pronotum dark brown with a pale area in the anterior median portion. Scutellum reddish brown with a median, impressed, transverse black line at each end of which is a white marginal area. Elytra pale brown, subhyaline. Veins pale, face creamy white, sutures black, black arcs on face either side of median line.

Genitalia: Female last ventral segment rounded from lateral margins to a produced posterior margin which is rounded on either side of a broad median excavation almost one-third the distance to base. The excavation is slightly roundedly notched at apex.

Holotype female and paratype females collected at La Guarda, D. F., Mexico, elevation 9800 ft., October 26, 1941. Female paratypes collected at Rio Frio, D. F., Mexico, elevation 10300 ft., September 22, 1941, Mt. Popo, Mexico, elevation 11,000 ft., and Puebla, Pue., Mexico, elevation 8500 ft., October 18, 1941, by Caldwell, Good, Plummer and DeLong. Paratype females collected at Rio Frio, D. F., elevation 9500 ft., October 18, 1945, by DeLong, Hershberger and Elliott.

Idiodonus anademus n. sp.

Resembling *turpiter* in general form and appearance but with distinct markings and female genitalia. Length 4.5 to 5 mm.

Vertex blunt and slightly produced almost twice as broad between the eyes at base as median length.

Color: Vertex pale with two broad transverse spots on margin between ocelli, slightly separated at middle. A quadrate black spot just beneath each ocellus. An angular black spot just above each ocellus. A median black line on disc, basal two-thirds orange brown, basal margin white. Pronotum dark brown with a median longitudinal pale stripe. A small quadrate black spot either side of median line not far from anterior margin. Scutellum orange brown, basal angles darker. A pair of round, black, median spots on anterior portion and a median transverse black line. Elytra brownish, subhyaline. Veins mostly brown alternated with white. Costal margin white. Face creamy white tinted with brown, sutures black and portions of arcs either side of middle, brown.

Genitalia: Female last ventral segment rather short, lateral margins rounded to posterior margin which is broadly, roundedly produced either side of a broad V-shaped median notch which extends about one-fifth the distance to base with a brown spot at apex causing it to appear more deeply notched. Male plates rather broad and convexly rounded to an acutely pointed apex.

Holotype female, allotype male and male and female paratypes collected at La Guarda, D. F., Mexico, elevation 9800 ft., September 5, 1939, by Plummer and DeLong. These were taken from pine.

Idiodonus nigridens n. sp

Resembling *anademus* in general form and appearance but with different color pattern and distinct genitalia. Length 5 mm.

Vertex bluntly produced, less than twice as wide between eyes as median length.

Color: Vertex white tinted with yellow. A pair of large black spots at apex which are tapered on outer margin and are somewhat transverse. A large black spot just beneath each ocellus and next the eye. A very small black spot just above each ocellus between which there is a broad transverse orange band. Pronotum orange brown with an inverted white T-shaped mark on the posterior portion. Scutellum orange brown, an inconspicuous impressed black transverse line at middle. Elytra brownish hyaline. Veins brown, alternately marked with white. Face yellowish, heavily marked with dark brown or black; sutures are broadly black and the arcs are fused next to the clypeus and are somewhat fused on their inner margins on upper portion of the face.

Genitalia: Female last ventral segment sloping from short lateral margins to form rather narrow produced rounded lobes either side of a broad excavation about one-fifth the distance to base which bears a broad rounded black tooth at middle. The tooth does not extend to the posterior margin of the segment. Male plates small, triangular, elongate, with pointed apices.

Holotype female collected at Cuernavaca, Mor., Mexico, elevation 4900 ft., October 21, 1941, allotype male and paratype males and females from Carapan, Mich., Mexico, elevation 5000 ft., October 2, 1941; Rio Frio, D. F., Mexico, elevation 10300 ft., September 22 and October 18, 1941; Tres Cumbres, D. F., Mexico, elevation 9100 ft., collected by Plummer, Caldwell, Good and DeLong, and Mexico City, D. F., Mexico, elevation 7500 ft., September 2, 1937, (M. F. 6189), collected in pine forest by Dr. A. Dampf. Paratype females collected at Rio Frio, October 18, 1945, elevation 9000 ft., by Hershberger, Elliott and DeLong.

Idiodonus incidus n. sp.

Resembling *nigridens* somewhat in general form but with entirely different coloration and female genitalia. Length 4.5 mm.

Vertex produced and bluntly angled, more than twice as broad between eyes at base as median length.

Color: Vertex with the marginal area white. The posterior two-thirds reddish brown with two round black proximal spots on apex and a black spot about the same size just above each ocellus. The dark coloration on the posterior portion extends from the line connecting these

two spots. Pronotum orange brown unmarked. Scutellum orange brown with an inconspicuous black transverse line on the middle, at each end of which is a small triangular white marginal spot. Elytra smoky subhyaline, the anterior end of claval veins white and the veins on the posterior part of the elytra paler. Face creamy white, sutures and dark arcs on either side of the face, black.

Genitalia: Female last ventral segment with posterior margin broadly roundedly convexly produced from base with a minute U-shaped notch at middle.

Holotype female collected at La Guarda, D. F., Mexico, elevation 8500 ft., September 5, 1939, by Plummer and DeLong Paratype females collected at Laguna de Zempoala, October 21, 1945, elevation 10,000 ft., in pine and fir forest by Plummer, DeLong, Hershberger and Elliott.

Idiodonus graeculus (Ball)

Thamnotettix graeculus Ball. Can Ent. 33 : 6, 1901.

A blunt headed species without markings on vertex or pronotum. Length 5–5 5 mm.

Vertex bluntly angled, more than twice as wide between eyes as median length.

Color: Vertex, pronotum, scutellum and face bright canary yellow, the disk of pronotum slightly tinged with brown, basal angles of scutellum darker. Elytra brownish subhyaline with spots of milky white coloration especially white areolar spots along the commissural line and clavus.

Genitalia: Female last ventral segment with the lateral angles rounded, between which the posterior margin is deeply excavated halfway to the base at the apex of which there is a spatulate process produced to the length of the lateral angles. Male plates rather long, triangular, with apices acutely pointed.

One specimen was collected at Saltillo, Coah., Mexico, elevation 7000 ft., September 23, 1931, by Good, Caldwell and DeLong. This is the only record that has been obtained to date for this species in Mexico

Subgenus Angulanus nov.

As compared with Idiodonus the vertex is bluntly angled and is angled with the face. In *Idiodonus* the vertex is rounded to the face. The first apical cell of the elytron is large and about as wide as long. The first anteapical is triangular and about half as long as the second anteapical. The apex of the first anteapical is oblique and does not extend as far apically as the apex of the second anteapical. The first anteapical tapers to a pointed anterior end and partially lies in the concavity formed by the constriction of the second anteapical on its apical half. There is only one cross nervure on the corium.

Genotype *Idiodonus incisurus* n. sp.

Idiodonus incisurus n. sp.

Somewhat resembling *graeculus* in general appearance but with a more produced vertex which is flattened at margin and with a different color pattern. Length 5 mm.

Vertex roundedly produced, less than twice as wide between eyes at base as median length.

Color: The face is bright yellow, unmarked, color extending over margin to vertex with a row of six somewhat fused brown spots just above margin. The central portion of disc is dark brown just posterior to this band except the longitudinal pale line at middle. A pale brown spot in each basal angle next the eye. Pronotum appearing brownish due to the mottled pigment throughout. Scutellum bright yellow, basal angles darker. Elytra pale subhyaline with spots of fuscus and veins dark brown. The color of the wings gives it a milky white appearance.

Genitalia: Female last ventral segment roundedly produced from the lateral margins to form the posterior margin which is broadly, convexly rounded either side of a median rather broad V-shaped notch extending about one-sixth of the distance to base. Male plates elongate, triangular, margins almost straight, apices pointed.

Holotype female, allotype male and paratype males collected at La Guarda, D. F., Mexico, elevation 8500 ft., September 5, 1939, by Plummer and DeLong. A series of male and female paratypes were collected at Tepotzlan, Mor., Mexico, September 11, 1941, by Good, Plummer, Caldwell and DeLong.

FURTHER STUDIES ON THE LIFE HISTORY AND DISTRIBUTION OF EUBRANCHIPUS VERNALIS (VERRILL)[1]

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During the winter and spring seasons of 1943 and 1944, field studies on the distribution and life history of the fairy shrimp *Eubranchipus vernalis* (Verrill) in northeastern Ohio were continued. Results of the studies made during the two previous years have been published earlier (Dexter and Sheary 1943; Dexter 1943b). Additional data have been secured on the geographic and seasonal distribution, limits of temperature and hydrogen ion concentration, fluctuations of abundance, new appearances and disappearances, sex ratio, and color characteristics of *E. vernalis*. Also, information on the life history of this species has been obtained by a weekly study of one pond over a period of several months each year and by observations of laboratory cultures of this fairy shrimp.

REVIEW OF FIELD COLLECTIONS. PORTAGE, SUMMIT, AND STARK COUNTIES—1943

During the third consecutive year of this study (1943), 61 pools and ponds in Portage, Summit, and Stark Counties, northeastern Ohio, were examined, including all of those from which any records of fairy shrimps had been known previously. Fifty-eight pools were restudied and three new stations were added. Because of the war-time restrictions on travel, it was necessary to drop 59 stations which had been included in the annual survey. Five others had dried out by the time they were reached, and many pools did not contain as much water as had been found in previous years. Table I gives a summary of the field collections for each year, and Figure 1 shows the location of all positive records.

The first specimens collected in the winter of 1943 were taken on February 4. These were smaller than those first collected in previous years, but the collection of February 11 compared very favorably in size with specimens collected from the same pond (Pond P7) on March 15, 1942, which in turn were comparable in development to those collected a week earlier the previous year. The last collection of the original population from this pond in 1943 was made on April 1. Five days later the pool dried up. The last collection there in 1942 was made on April 23, at which time the pond had become very nearly dry. A second population developed in this pond after refilling on April 13, 1943. Small numbers of *E. vernalis* were collected between May 10–25. Only three ponds (Ponds P43, S1, C2) had more abundant specimens of *E. vernalis* in 1943 than in 1942, while twelve ponds (P17, P18, P79, S3, S5, S12, S18, C6, C7, C9, C10, C12) were found to contain a smaller population in 1943 than during the preceding year.

No species of the anostracan phyllopods was collected in 1943 other than *E. vernalis*. *Pristicephalus bundyi*, which had been collected in one pool in 1942, was not found again. Because of the much smaller population of fairy shrimps in that pool and the limitation of time for collecting, only 31 specimens were taken. Had a more thorough sampling been made, it might have disclosed the presence of *P. bundyi* for another year.

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[1]Acknowledgment is made to those persons who have kindly contributed records as indicated in the paper, especially to Mr. Charles H. Kuehnle, who has assisted the writer on collecting trips in Stark County, and to Dr. N. T. Mattox, who has read the manuscript. Portions of this paper have been read before the Zoology Section of the Ohio Academy of Science and before the Ecological Society of America.

A total of 24 stations was found inhabited by *E. vernalis* during the spring of 1943 (7 in Portage, 7 in Summit, and 10 in Stark Counties). Altogether 30 pools have been known to contain this species at some time during the period between 1941 and 1943.

REVIEW OF FIELD COLLECTIONS. PORTAGE, SUMMIT, AND STARK COUNTIES—1944

During the season of 1944, fifty-five of the established stations and five new pools were investigated (35 in Portage, 12 in Summit, 13 in Stark Counties). Again, all pools from which any collections of fairy shrimps had been made in the past were restudied. During the fall of 1943 and the winter of 1944, most of the temporary pool depressions contained no water, and for the most part did not fill with water until the first week of March. The month of December, 1943, was the driest since 1925. The spring rains, however, filled the pools. (See Table I and Figure 1 for collecting data).

TABLE I

FLUCTUATIONS OF POPULATIONS OF THE FAIRY SHRIMP, *Eubranchipus vernalis* IN THREE COUNTIES OF NORTHEASTERN OHIO

STATIONS	1940	1941	1942	1943	1944
P7, P18, P79, S1*, S5, S11, S14, C7* (*S1, C7, also + in 1940)		+	+	+	+
S18, C2, C3, C6, C9, C11, C12		–	+	+	+
P88, P89, C13		–	–	+	+
P91, P92, C14		–	–	–	+
P17, P43, S12		0	+	+	+
P40, P55, P58		0	0	0	+
C8	+	+	0	+	+
P30, P50		+	0	0	+
P80		+	+	0	+
S2	+	0	+	0	+
S4		+	+	0	0
S3	+	+	+	+	0
C10		–	+	+	0
P37		+	0	0	0
P1, P8, P12, P14, P22, P42, P47, P48, P49, P54, P66, P68, P69, S7, S8, S13		0	0	0	0

+ = *E. vernalis;* 0 = No fairy shrimps; – = Not Studied.

Out of a grand total of 127 pools studied in the three counties over a period of four years, thirty-six have contained *E. vernalis* at one time or another, and thirty-two of these had records in 1944. This year was a very favorable year for the fairy shrimps. Eleven of the pools (P17, P79, P89, S1, S11, S18, C2, C7, C8, C12, C13) had definitely more abundant populations than they had had during the preceding year, while only four (P7, S14, C6, C9) had populations that were

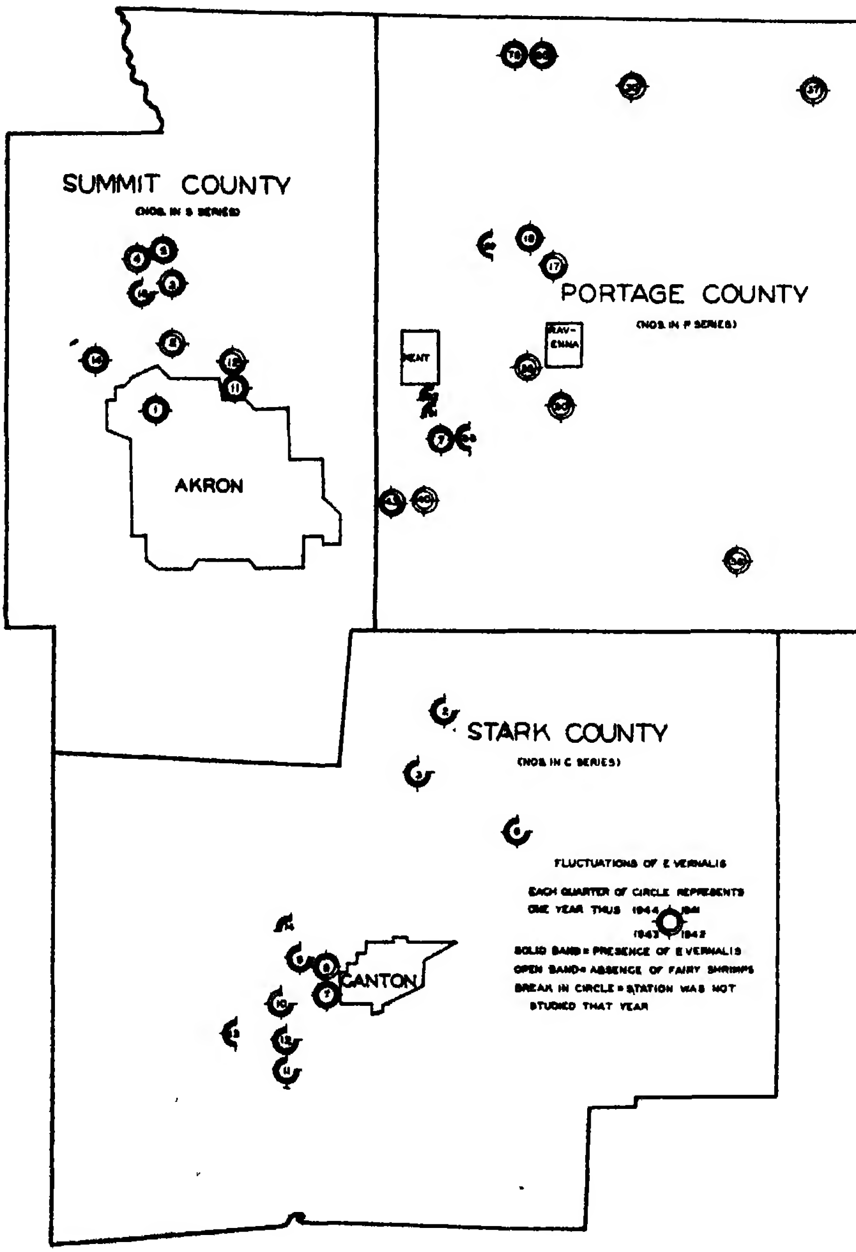

FIG. 1. Map of Portage, Summit and Stark counties, Ohio, showing the locations from which *Eubranchipus vernalis* has been collected.

less abundant in 1944 than in 1943. Nearly all of the observed annual changes are of such a magnitude as to be easily detected. Sixteen stations have had no records of fairy shrimps for four consecutive years, six others, for three years; and two of the new stations did not contain specimens. The 1944 populations were about six weeks later in appearing than during the previous year. Specimens collected on March 25, 1944, were about equal in size and development to those collected on March 4, 1943. Egg sacs were first found developed in the season of 1944 on April 2, on specimens collected at Canton.

OBSERVATIONS ON THE LIFE HISTORY AND ECOLOGICAL RELATIONS OF E. VERNALIS

When specimens were first collected on February 4, 1943, they were already 4.65 mm. in length, which fact was rather unexpected because of the long, cold winter weather which preceded this date. A sample was collected each week after February 4, until the pool (P7, near Brimfield) dried up on April 6. A rather uniform sample of ten individuals was measured from the collection of each week. Table II gives the measurements of total length which were made from the anterior margin of the head to the extremity of the caudal furca, but not including the filaments. Data are also presented on the temperature and hydrogen ion concentration of the pool on the dates of collecting. The rate of growth was erratic. Egg sacs first appeared on the females in this pond on March 25. The average maximum size attained was 15.44 mm. which was reached by April 1. Comparison should be made between these data and the growth of *E serratus* studied in a pond of east central Illinois (Dexter and Ferguson, 1943). As nearly as could be determined only one generation of *E. vernalis* was present, and the samples were for the most part very nearly uniform in size on any one day.

The week following the drying out of Pond P7, it filled up again from a series of snow squalls and rainy spells. On April 17, 1943, and again one week later, a plankton sample was taken throughout this pasture pool, but neither time were the nauplii or metamauplii of *E. vernalis* found. Great quantities of copepods and ostracods and a number of insect larvae had hatched and given rise to a very rich plankton population. It was as rich in species and in quantity as the first plankton sample which had been taken on February 4. On May 10, however, three immature, female fairy shrimps which averaged 10.7 mm. in length were collected. Nine days later two males were taken in the net after a careful search, and on May 25 one male and two females were found. Those of the last collection were of the characteristic colors for fully developed, mature individuals, and were the largest specimens seen during that season, averaging 25.8 mm. in length.

While it may be possible that this second population came from eggs laid by the first generation, which lived in the pool during the preceding months, it is more likely that it came from eggs which had been deposited during some earlier year. Weaver (1943) has shown experimentally that the eggs of *E. vernalis* can hatch without being frozen, contrary to a common belief that freezing is necessary before hatching will take place. However, Avery (1939) and Weaver (ibid.) found that a considerable rest period seems to be required before hatching will occur. Whether the eggs are dried or frozen or not some of them will hatch after a lapse of time. Weaver found an interval of twelve days between the "shock" of drying or freezing and the hatching of the eggs. The number of individuals which he succeeded in hatching under various controlled conditions in regard to freezing and drying was not great, and in no case did all of the eggs hatch. Contrary to the work of Weaver, Castle (1938) observed that some eggs of *E. vernalis* hatched in an aquarium without having been dried, and Avery (1939) succeeded in hatching eggs which had never been dried, but had had a resting period of one year. His experimentally dried eggs failed to hatch. Mathias (1937) had stated earlier that desiccation is not necessary for the development of phyllopod eggs.

TABLE II

COMPARISON OF LIFE HISTORY OF *Eubranchipus vernalis* IN POND P7 IN 1943 AND IN 1944

Date (both years)	1943 °C	1943 pH	1943 MM in Length	1943 Amt. of Growth in MM	1943 Notes	1944 °C	1944 pH	1944 MM in Length	1944 Amt. of Growth in MM	1944 Notes
Feb. 4	3 0	5 9	4 65		First collection of season: under ice: pool not full; specimens orange-pink					
Feb. 11	0 0	5 9	4 83	0 18	Under ice.					
Feb. 18	0 5	6 0	6 25	1 42	Under ice					
Feb. 25	4 5	6 0	6 87	0 62	Under ice					
Mar 4	0 5	6 1	8 31	1 44	Under ice					
Mar. 11	1 0	6 3	9 03	0 72	Under ice	2 0	5 3	2 53		First collection of season; under ice
Mar 18	9 0	6 3	11 76	2 73	Males light green: females bluish-gray	5 5	5 9	5 11	2 58	Pond about half full.
Mar. 25	11 5	6 4	12 43	0 67	Egg sacs developing.	16 6	6 15	8 56	3 45	
April 1	21 0	6 4	15 44	3 01	Pond half dried.	4 7	6 1	11 92	3 36	Second antennae of males well developed.
April 8					Pond dried up April 6; refilled April 13	8 8	5 9	14 40	2 48	Pond nearly dry; egg sacs developing; eggs small.
April 15						10 5	6 1	16 75	2 35	Pond refilled to about half full; males greenish; females bluish-gray; egg sacs large.
April 22						13 5	6 1	19 00	2 25	All mature except one specimen — probably a late hatching
April 29										Pond dried out
May 10			10 7		Pond nearly full, 3 immature females collected, colorless					
May 19	21 0	6 4	22 5	11 8	2 males collected, colorless					
May 25	17 5	6 8	25 8	3 3	1 male, light green, 2 females, bluish-gray Last collection.					

Weaver did not succeed in hatching eggs which had not been allowed to dry, and had been kept in water for nine months. The writer has attempted to hatch eggs of fairy shrimps by drying, freezing, and the prevention of drying and freezing, but without success. In these experiments, however, small numbers of eggs were used, and it is apparent that the factors regulating the hatching of eggs of fairy shrimps are little understood. Weaver concluded that drying, freezing, and a long rest period are usual before hatching occurs. He believes that drying is important and that freezing seems to induce hatching.

From the experiments of Avery (1939) and Weaver (1943) and their finding that a period of rest is required before hatching will take place regardless of environmental factors, and from the results of field observations reported here, especially of sudden appearances and disappearances of populations of considerable size, the following interpretation first developed by Hesse (1924) from observations reported from Europe and Africa has been adopted. The eggs of *E. vernalis* are without doubt widely distributed in the soil of depressions and dried-out pools. Probably myriads of such places contain some eggs which have been present over varying lengths of time. The question of how fairy shrimps or their eggs are introduced into these temporary pools is at the present time largely a matter of conjecture. Mathias (1937) in his monograph on the biology of the phyllopods explains the dissemination of the eggs as being carried by the wind, and on amphibians, water birds, and other animals which travel from pool to pool. He also states that phyllopod eggs pass through the digestive tracts of amphibians, birds, and possibly mammals, and still remain viable. Some years, when conditions are favorable, many of these latent eggs which have been scattered about will hatch in the spring when the depressions are filled by melting snow and ice. Other years they may fail to hatch in any certain pool, but remain viable for another season. Some eggs may not hatch for a number of years. The radical changes from year to year are probably the result of a successful hatching or a failure to hatch rather than being a new introduction or a total elimination of the species since it was last recorded. This explanation seems the most plausible in view of what is known of the life history of the species and the sporadic nature of its geographic and seasonal occurrence.

It has been noted that sometimes fairy shrimps do not appear in deep pools as early as they do in shallow water. Specimens of *E. vernalis* collected from pond P88 on March 18, 1943, for example, were only 4.05 mm. in length. The same day, specimens from Pond P7 nearby had an average length of 11.76 mm. Those from the deeper pool were at that time approximately the size of specimens collected from station P7 six weeks earlier. After the fairy shrimps from the deeper pool reached maturity they averaged only 13.8 mm. in length (May 5, 1943).

In the season of 1944 most of the pools did not fill up until March 6. *E. vernalis* was not found in Pond P7 until March 11. At that time the fairy shrimps were only 2.53 mm. in length, while they were 9.03 mm. on that date of the preceding year and had been active in the water for some five weeks preceding that time. However, the individuals of the 1944 population grew rapidly, reached maturity in a short time, and attained great size. During the development of the 1944 population, the pond water was somewhat warmer than during the period of development of fairy shrimps of the same size in the 1943 population. This difference explains without question the different rates of development and maturity. The fairy shrimps were present in Pond P7 in 1944 until it dried out sometime between April 22 and 29.

During the month of March and early in April of 1944 pond P88 for some reason failed to fill with water. No more than an inch or two collected in the lowest portion of the trough, and much of that was in the form of scattered puddles. A plankton sample taken from these shallow puddles on March 18 contained two

metanauplii of fairy shrimps. No others were found in earlier or later samples. On April 11 a rainstorm of 1.49 inches filled this pond. On April 22 a large population of fairy shrimps was found in the water. They grew and matured rapidly in the warm water (see Table III). The eggs were developing on the females within two weeks after hatching, and the population completed its entire existence as free-swimming organisms in little more than thirty-two days. The population disappeared after May 13. Water remained in the pond for several weeks longer, but had an afternoon temperature of over 21 degrees C. which seems to be the limit beyond which *E. vernalis* does not live for long.

TABLE III

Development of *Eubranchipus vernalis* in Pond P88, Season of 1944

Date	°C	pH	MM in Length	Amt. of Growth in MM	Notes
April 22		. .	4 20		Pond filled April 11, late hatching; specimens orange-pink.
April 29	15 0	5 8	12.90	8 7	Orange-pink in color, egg sacs developing.
May 6	14 0	5 5	15 35	2 45	Males light green; females bluish-gray; egg sacs well developed.
May 13	21 1	5 6	16 30	0 95	Last collection
May 20	21 7	5 9	.	. .	*E. vernalis* not present; pond still contained 1 5 ft water

E. vernalis has been found in a range of water temperature from 0° to 21° C. Individuals kept in aquaria in the laboratory with an average water temperature of around 20° C. lived on an average of 6.5 days. The longest surviving individual of each culture averaged 16.5 days. The longest surviving of any one individual was 30 days. This species has been found in a pH range from 5.3 to 7.6 with instances for almost every graduation between these limits. Mathias (1937) reported that phyllopods in general prefer alkaline water and do not withstand acid water. The experience of the writer has been that *E. vernalis* has a wide range of tolerance and probably could live in hydrogen ion concentrations found in most natural pools of water whether acid or alkaline.

It has been observed that on cloudy days fairy shrimps have a tendency to remain at or near the bottom while on sunny days they swim near the surface of the pools.

It is commonly believed and often repeated in textbooks that the first generation of fairy shrimps consists entirely of females which reproduce parthenogenetically by means of "summer eggs." Later in the season, it is believed by some, males are produced which fertilize the winter eggs. These presumably produce the first generation of females the following season. A number of specimens of *E. vernalis* collected early in the season before any were mature and kept in an aquarium developed into males, hence they must have hatched from "winter" eggs. Also, many males were collected in the pond before mature females had developed. In addition, egg sacs were not fully formed in the specimens of Pond P7 until 5 days before the pond dried out. It is evident that for this species the males hatch from winter eggs, and sometimes, at least, there is but a single generation in a season.

In another pond nearby, however, it seems quite possible that more than one generation was produced in one season. This pond (Station P88) is a deep depression which does not dry out completely every year, although usually it does. It has steep banks, but they are at least partly exposed during the summer months. Specimens collected from this pond on March 18, 1943, were only as much devel-

oped as those collected in the shallow water of Pond P7 on February 11. However, the population in Pond P88 continued until May 10, some five weeks after the first population in Pond P7 disappeared. During April, specimens of all sizes and in all stages of development could be collected at the same time from the deep pond. A number of other pools, especially deep ones, contained specimens in various stages of development suggesting that more than one generation might be present. Some pools had two distinct size groups. Pond P43, for example, had two distinct size groups collected under ice as early as March 21. Whether these represent two generations (one group was sexually mature) or whether they simply hatched at different times is not known. Mathias (1937) claims that two kinds of eggs are produced—those which hatch immediately, and resistant eggs which can withstand desiccation for a number of years. The writer has not been able to obtain a second generation of fairy shrimps in an aquarium.

Avery (1939) reported collecting *E. vernalis* from a body of water not known to be dry over a period of seven years From this fact and from the results of hatching experiments he concluded that the common belief that this shrimp occurs only in temporary springtime pools does not agree with the evidence. An abstract of his paper (Biological Abstracts 15: 3340) conveys a false impression through the unfortunate omission of the word "only" in the above statement As the writer has already pointed out, (Dexter, 1943a) nearly all records of fresh-water fairy shrimps are from temporary spring pools, although a few records are known as the one reported by Avery where fairy shrimps are found in ponds which do not dry out entirely, but which have a dry margin during the summer months. Shelford (1937) has quoted an observation made by Child in the Chicago region that fairy shrimps sometimes appear in ponds which seldom dry out, but which after a long period of drought do dry out. The following season, after refilling with water, the pond is found to contain fairy shrimps. It may be that other records of fairy shrimps found in ordinarily permanent ponds can be explained by the same situation. In such ponds, fairy shrimps might be an important item of food for fishes, as it is sometimes mentioned in zoological literature. Usually, however, fishes are not found in the same community with fairy shrimps.

SEX RATIO

Textbooks and manuals often state that the males of fairy shrimps are relatively scarce. Very little is to be found in original literature concerning the sex ratio Weaver (1943) found five females to one male on March 18, 1940, but later in the season the proportion of males increased as the shrimps got larger. After March 30 the males began to disappear. In regard to this problem, samples have been taken by the writer from a variety of ponds and over a period of time to determine the proportion of sexes as found for *E. vernalis*. A sample of 145 specimens collected in the spring of 1941 had a ratio of 55 males: 90 females (1 : 1 6). Of 240 specimens collected during the following spring a ratio of 100 males: 140 females (1 : 1.4) was found. On March 3, 1943, 100 specimens taken from Pond P7 showed a ratio of 32 males: 68 females (1 : 2.1). One week later another sample of 100 removed from the same pond had nearly the same ratio—35 males: 65 females (1 : 1.9). A mixed sample of 141 specimens taken from various pools during the same spring had a ratio of 55 : 86 (1 : 1.6). A similar sample of 364 individuals collected in 1944 also had a ratio of 1 : 1 6. In contrast to these a sample of 122 individuals collected from several pools in Stark County on April 3, 1943, showed the reverse trend with a ratio of 80 males: 42 females (1 : 0.5). This is the only time the writer has collected a sizable sample in which the males predominated. The average of all of these (1212 individuals) gives a ratio of 1 male: 1.5 females. It is clearly evident that for *E. vernalis* in the years and regions covered in this study, the males have been much more abundant than is commonly

believed. Contrary to the finding of Weaver, the writer has not observed the sex ratio to change during the season.

COLOR

While all of the specimens of *E. vernalis* of comparable age and development collected from the same pool have been uniform in color, the color does change as the individuals mature (Dexter 1943b). In the report cited, observations of the change in color were made by successive collections from the same pools. During the spring of 1943 this observation was confirmed by individual specimens kept in culture in the laboratory. On February 18, 4 specimens of the typical orange-pink or salmon color were placed in an aquarium. On March 4 this color began to fade in a surviving male specimen and by the next day it was light green in color as reported earlier for mature males of *E. vernalis*. The specimens in the pond from which the collection was made were still orange-pink at this date Another sample was taken at this time and also placed in an aquarium. Six days later the orange-pink color began to fade and the egg sacs developed. On March 23 the females were entirely bluish-gray in color as reported earlier for the mature females Four days later they turned the same cream color observed in old specimens of *E. serratus* when kept in culture for several days beyond the time of maturation. A number of females collected on March 11, 1943, developed egg sacs and turned bluish-gray on March 18. On this day, the largest female specimens in the pond were just developing the color characteristic of the adults, while the majority of the pond specimens were still orange-pink.

In the season of 1943 a population of *E. vernalis* was discovered which had a most unusual color. On April 3 the writer with Mr. Charles H. Kuehnle, collected a sample of *E. vernalis* from a shallow swamp-pond near Canton, all of the specimens of which were light blue in color Not only those collected, but all of the individuals seen swimming about in the water had the same characteristic coloring. This pigment was found throughout the body, but was particularly noticeable in the head and on the tips of the appendages. The writer had never before seen a fairy shrimp population of such a color. It was suggested by Dr C E. Venard that the light bluish color might be caused by blue-green algae attached to the cuticle of the fairy shrimps. A sample from the Canton pond was sent to Dr. C. E. Taft for examination, but no algae were found. Dr. Taft reported that he has seen fairy shrimps with algae, usually of the genus *Characium*, attached to the animals, but he knows of no record where blue-green algae have been similarly found. The following year Mr. Kuehnle and the writer collected again from this swamp-pond. On April 2, 1944, all of the specimens found were of the usual orange-pink or salmon color, and not a single one had the peculiar light blue color found the preceding year. On April 15 Mr. Kuehnle made another collection from this location and the specimens were still normal and uniform in color. It is possible that some chemical property of the swamp water during the season of 1943 was responsible for the unique coloring of the shrimps that season.

ADDITIONAL RECORDS OF ANOSTRACAN PHYLLOPODS COLLECTED IN OHIO

In addition to the records of this survey and the references which have been cited (see Dexter and Sheary, 1943; Dexter, 1943b), a number of collections and records from Ohio have come to the attention of the writer which are presented in Table IV. Specimens from the following collectors have been identified by the writer: Vickers, Azary, Chiavetta, Surrarrer, Kuehnle, Wilson, Geist, Venard and Gerberich, Blaydes, and Rice. Dr. N. T. Mattox identified those collected by Clark as well as his own specimens. Dr. R. M. Bond identified those collected at Oberlin. The following made their own determinations: Linscheid, Hazard, Dreyer, Stehr, and Gier. All of the specimens which have been identified to

TABLE IV

ADDITIONAL RECORDS OF ANOSTRACAN PHYLLOPODS COLLECTED IN OHIO

County	Collector	Location	Species	Notes
Mahoning	Ernest Vickers, Park Naturalist, Mill Creek Park	Mill Creek Park, Youngstown	*E. vernalis*	Fairy shrimps have been observed at various times over many years. One collection only, without date, has been saved.
Lake	Kenneth Chiavetta	North Chagrin Reservation	Unknown	Abundant specimens collected from single pool on April 12, 1942. None found in several other nearby pools. Specimens disintegrated before determination could be made.
	Ross Azary	Eastern edge of Painesville	*E. vernalis*	Abundant specimens collected from a pasture pool on April 8, 1944. None found in two nearby pools.
Cuyahoga	Alfred G. Linscheid, Shaker Heights Schools	Warrensville Heights	*E. vernalis*	Abundant specimens found in March of each year between 1931 and 1943 in an extensive swamp-pond opposite the Warrensville Farm buildings.
	Kenneth Chiavetta	Fairview	*E. vernalis*	Specimens collected on April 20, 1942, from a temporary pool.
	Thomas C. Surrarrer, Baldwin-Wallace Col.	Berea	*E. vernalis*	Specimens collected about April 1, 1930, from a pool 1,000 yards from Biology Laboratory.
		Rocky River Reservation	*E. vernalis*	Specimens collected about May 10, 1941, from a temporary pool in woods just beyond junction of the East and West Branches of Rocky River.
Lorain	Members of Biology Dept., Oberlin College	Oberlin	*E. vernalis*	Collections have been made from many pools over many years time, but especially "Cemetery Pond" which Dr. Hope Hibbard says has had specimens every year since first examined.
Wayne	Members of Biology Dept., College of Wooster	Wooster	Unknown	Fairy shrimps have been collected every year from pools near Wooster for a number of years. Specimens have not been preserved. (Information from Dr. R. V. Bangham and Dr. W. P. Spencer.)
	James Anderson	Wooster	Unknown	Some years ago his daughter collected from a pool which has since been filled in road construction.
Richland	Mariel J. Aberle, Mansfield Senior High School	Mansfield	Unknown	Fairy shrimps found just once in Mansfield area. A collection was made in about 1929 at southern edge of city. Return visits year after year failed to find them again. Later, pond was drained and a road bed was made there. Other pools examined have never contained specimens.
Crawford	Charles H. Kuehnle, Lincoln High School, Canton	Bucyrus	*E. vernalis*	Of 8 pools examined on April 9, 1944, 6 contained *E. vernalis*. Specimens in a flooded, cultivated field were very abundant; in one pasture pool they were common; in three others fairly common; and in one, occasional specimens were found
Marion	Thomas D. Bain, Harding High School, Marion	Marion	Unknown	Fairy shrimps have been collected for a number of years in temporary woodland-pasture pools. In some pools they have been abundant in the early spring.

Seneca	**Ira T. Wilson, Heidelburg College, Tiffin**	Tiffin	*E. vernalis*	Great abundance of *E. vernalis* was found in some woodland pools 1½ miles northeast of Tiffin in March of either 1924 or 1925. Collections were made just as ice began to break up.
Wood	**Edwin L. Moseley, Bowling Green State University**		Unknown	Fairy shrimps have been collected in early spring months in various parts of Wood County over a period of years.
	C. H. Otis, Bowling Green State Univ.	Weston, Portage, Scotch Ridge, Pemberville, Bowling Green	Unknown	Preceding 1943, collections of fairy shrimps were made every spring for a number of years in many pasture pools in the county, but especially in Weston Cemetery Pond. None has been collected in recent years because of dry seasons and travel restrictions. One pond near Pemberville has been drained.
Lucas	**Archie N. Solberg, University of Toledo**	Ottawa Hills Village	Unknown	Fairly common specimens have been collected for several years from a single pond.
Paulding	**Clarence F. Clark, Ohio Div. of Conser. and Nat. Resources**	Brown Township	*E. vernalis*	Two collections from hog wallows were made on April 15, 1937.
		Auglaize Township	*E. vernalis*	One collection from a Beech-Maple woodland pool was made on May 1, 1939.
Mercer	Clarence F Clark	Franklin Township	*E. vernalis*	Specimens collected on April 2, 1942, in a temporary woodland pool.
Auglaize	Clarence F Clark	St. Marys, Washington and Moulton Townships	*E. vernalis*	Twelve pools of various types—roadside, woodland, pasture pools, ditches, and hog wallows—were found inhabited by *E. vernalis* during March and April of 1942.
		Logan Township	*E. vernalis*	Specimens were collected from a roadside pool on April 1, 1944
				The first known record of *E vernalis* from Auglaize County is a locality record cited by Daday (1910) for Wapakoneta.
Shelby	Clarence F. Clark	McLean Township	*E. vernalis*	Two woodland pools were found inhabited by *E. vernalis* on April 24 and 25, 1942.
Logan	Donald E. Geist, Bellefontaine High School	Bellefontaine	*E. vernalis*	Abundant fairy shrimps were found in a temporary pool 1½ miles south of Bellefontaine on April 1, 1937. About a week later not a single specimen could be found. Later that year the pool was made into a corn field.
Montgomery	Charles A. Dambach, Ohio State University	Dayton	Unknown	Abundant fairy shrimps in a series of temporary pasture pools four miles east of Dayton were collected in early April of 1939. The specimens were lost through poor preservation before identification could be made.
Warren	Norman T. Mattox, Miami University	Fort Ancient	*E vernalis*	On April 17, 1940, and again in April of 1941, *E. vernalis* was collected from temporary pools on top of the ridge inside the old earthen-works.
	Frank O. Hazard, Wilmington College	Fort Ancient	*E vernalis*	A collection was made on April 11, 1944, at the same location as above.
Clinton	Frank O. Hazard	Clarksville	*E vernalis*	Many collections have been made from pools in a pin oak swamp-forest on an upland flat over a period of years.

TABLE IV—(*Continued*)

County	Collector	Location	Species	Notes
Clermont	William L. Dreyer, Univ. of Cincinnati	Goshen	*E. vernalis*	A collection was made on March 6, 1942, from the same pool from which collections were made by Ward (1940) in 1937 and 1938.
Franklin	Carl E. Venard and John B. Gerberich, Ohio State University	Columbus	*E. vernalis*	Collections were made from 8 pools in the "dyke area" of Columbus in the spring months of 1942–1944. They were common each year.
	Glenn W. Blaydes, Ohio State University	Worthington and Columbus	*E. vernalis*	Observations and collections have been made from 3 pools over a number of years. Fairy shrimps were present every year, and collections were made as follows: On March 3, 1936, on Route 161 east of Worthington; on March 19, 1938, and April 16, 1944, from two pools on Cooke Road north of Columbus. Abundant specimens have been found in all three pools.
Delaware	Members of Zoology Dept., Ohio Wesleyan University	Delaware	*E. vernalis*	Dr. E. L. Rice made a collection of *E. vernalis* in 1911. Burton (1916) made 7 collections between March 3 and April 13 from a pool northwest of Delaware. Hooker (1938) made 16 collections between January 6 and April 15 from the same pool. Both of these list identification as Chirocephalus, which is probably incorrect. Dr. Rice has collected fairy shrimps from the same pool and from another nearby; also from 2 swamp pools south and southeast of Delaware. Members of the department have collected fairy shrimps for many years from the above pools. (Information from Dr. W. F. Hahnert.)
Central Ohio (Portions of Franklin, Delaware, Licking, Knox, Morrow Cos.)	Lawrence E. Hicks, Ohio State University	A belt some 10 miles wide between Worthington and Mt. Vernon	Unknown	Between 1928–1934, some 600 pools were examined for Algae. Approximately 40 were found inhabited by fairy shrimps.
Hocking	J. Arthur Herrick, Kent State University	Sugar Grove Region	Unknown	On April 4, 1942, fairy shrimps were observed in a single pool in which they were common.
Athens	William C. Stehr, Ohio University	Athens	*E. vernalis*	Specimens were collected from a pool along R. R. tracks in Athens every year between 1932–1942. None was found there in 1943. On March 24, 1942, a collection was made from a pond on U. S. Route 50, two miles east of Athens, but in the spring of 1944 none was found there.
	H. T. Gier, Ohio University	Athens	*E. vernalis*	Specimens were collected in April of 1942 from a pond 1½ miles north of Athens.

species are *Eubranchipus vernalis* (Verrill). In all likelihood the specimens recorded in Table IV as "unknown" were *E. vernalis* inasmuch as it is the only common, widely distributed species in Ohio. The specimens from Delaware County listed by Burton and Hooker as Chirocephalus were probably misidentified as this genus has been recorded but once from North America (Creaser 1940), and collections from the same pool studied by them and from nearby pools during other years, so far as known, have been *E. vernalis*.

SUMMARY

The third and fourth seasons of an annual survey of fairy shrimp populations in Portage, Summit, and Stark Counties, Ohio, have yielded the following results.

1. Twenty-four pools out of sixty-one studied in 1943, and thirty-two out of sixty studied in 1944 contained *Eubranchipus vernalis*, the only species collected during those years.

2. The populations of *E. vernalis* varied considerably each season. Some pools formerly inhabited failed to contain fairy shrimps during a certain season, while some other pools which lacked them in former years developed large populations. Considerable fluctuation of abundance was found from year to year in some pools.

3. In the season of 1943 the fairy shrimps appeared early, and the eggs had probably hatched in the winter months of 1942. Most of the pools dried up early, however, and very few fairy shrimps could be collected after April 6.

4. The spring of 1944 was a very favorable one for *E. vernalis*, which was found in more pools and in greater abundance in most cases than during the preceding three years. In 1944 the spring pools did not fill with water until the first week of March. However, the fairy shrimps developed rapidly after that time and matured by the middle of April. Some populations continued until May 13.

5. A sample was collected and measured from pond P7 each week during both years from the time they were first observed until they disappeared from the pond. All data are presented in tabular form.

6. Evidence is presented to prove that males as well as females hatch from the "winter" eggs.

7. In many cases only a single generation is present during one season.

8. If dried-out pools are refilled in the spring before the onset of hot weather, another population may develop as was observed in pond P7 in the spring of 1943. If a pool does not fill up until late in the spring, it may develop a population which will develop rapidly as occurred in pond P88 in the late spring of 1944.

9. The sporadic distribution of fairy shrimps and the sudden annual changes which occur in many ponds, together with published experimental data on hatching, would indicate that the eggs of fairy shrimps are widely distributed over the ground, and they may or may not hatch any one year. Some of the eggs probably remain viable over a number of years before hatching. Thus, sudden changes of appearance and disappearance can best be explained.

10. *E. vernalis* has been found in temperature ranging between 0° and 21° C, and in hydrogen ion concentration ranging from pH 5.3 to 7.6.

11. The sex ratio of *E. vernalis* averages 1 male to 1.5 females.

12. Color changes have been observed in specimens maintained in the laboratory. The orange-pink or salmon colored immature forms change to light-green males and bluish-gray females. A population of light-blue individuals of both sexes was found in one pond in 1943 All specimens of this pond had the same unique coloring.

13. Recent records of fairy shrimps are reported from 24 of the 88 counties of Ohio.

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ERYTHRONEURA OF THE OBLIQUA GROUP FROM OHIO AND TENNESSEE

(HOMOPTERA: CICADELLIDAE)

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An attempt is made to bring the work[1] on the obliqua group of *Erythroneura* up-to-date. Descriptions of five new species, new records for Ohio, corrections and synonymy are included

Early in April, 1945, large numbers of *Erythroneura* were observed congregating on stones in swift-running streams, where they could be collected in numbers with an aspirator Those taken in Delaware County, upon closer examination, proved to be almost exclusively members of the obliqua group, and males Further collecting in this manner in Delaware and Hocking Counties showed that members of other *Erythroneura* groups had the same habit, but it seemed to be a characteristic of males only. A great variety of species occurred.

Unless other collectors are mentioned all specimens were taken by D. J. and J. N. Knull and are in collection of The Ohio State University or of author.

Erythroneura alata n sp

Figure 5

Ground color white, vittae bright red Vertex with even-sided inverted U, rounded at apex, dusky area fills center; continued across pronotum as broad diverging vittae, space between them entirely dusky; scutellum dark, basal angles lighter in some specimens; elytra with broad claval vittae almost filling clavi, but for smoky area adjacent to scutellum, corial vitta broad, upper half appears to be joined to middle third of claval vitta by dark band of dorsum which shows through elytra; costal margin pellucid orange on basal part becoming broadly reddened toward crossveins; crossveins and adjacent part of longitudinal veins red, spots before crossveins and apical cells dusky, inner two cells translucent; small circular area around apices of clavi paler than rest of dorsum. Below a projection of vertexal U over apex of head, face dark, especially toward edges, legs pale, spines of hind femora dark, venter and dorsum chiefly dark.

Genitalia: Female, last ventral segment produced on middle third, pale. Male: Style with large foot, heel not projecting, base curved forming arc with inner margin of posterior point; anterior point narrow, projecting laterally, curved up; posterior point broad, three times as long and broad as anterior point and sharp-pointed. Aedeagus in lateral view short and heavy, ventral surface straight, dorsal sharply cut in before middle, and broadly swollen toward flattened tip, a pair of processes arises at ventral base of shaft, broadens into wing-like structures serrate on outer margins on apical half, narrowing to sharp, straight, spine-like apices.

Length: 3 mm.

Male holotype, Columbus, May 11, 1938; allotype, May 19, 1938; and paratypes, June 9, 1938; Delaware Co., April 2, 1945; April 26, 1944; April 30, 1944; August 27, 1942; Sept. 19, 1943; Oct. 3 and 10, 1943.

Near *E. funesta* Beamer in genital characters, but with a quite distinct color pattern. It bears somewhat the same relationship to *E. funesta* Beamer that *E. plena* Beamer does to *E. repleta* Johnson. In coloring it resembles *E. rufostigmosa* Beamer, but is darker.

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[1]D. M. Johnson, The Ohio Biological Survey Bulletin 31, issued July 8, 1935.

Erythroneura anomala n. sp.

Figure 9

Small, ground color creamy white with rather broad orange markings as follows: Vertex with inverted V broadly touching eyes, continuing across pronotum as two slightly diverging vittae; scutellum with tip orange, basal angles pellucid yellow; venter and dorsum yellow, abdominal segments and face more or less orange-tinged; a few black spines on hind femora Elytra with orange oblique vittae, one on clavus, one on lower middle of corium, and one along costal margin; spots before crossveins and apices faintly dusky.

Inner male genitalia: Style with small rather square foot, heel very prominent, projecting down, its outer edge parallel with outer edge of toe, base curved, anterior point short, sharp, evenly joined to posterior point which is merely a small sharp projection. Aedeagus in lateral view broad, short and straight, with flattened dorsally projecting apex, and sides with pair of lateral broad projections straight out from middle, about as broad as shaft, bent down and narrowed toward apices.

Length: 2.5 mm.

Described from three males, holotype and paratype, Hocking Co., April 26, 1938; and Knox Co., May 8, 1933, D. M. Johnson, *Carpinus*.

A small member of the group, resembling *E. mansueta* Beamer somewhat in character of inner male genitalia.

E. autenae Johnson instead of *auteni*, as in original description. Additional specimens have been taken from Delaware Co.

E. caerula Beamer, from *Hypericum* sp., Scioto Co., June 10 and 17, 1944.

E. cauta Beamer, Delaware Co.

E. coarctata Beamer, Fig. 2, Hocking Co., April 17, 1938, and May 5.

E. cotidiana Beamer, Fig. 4, Hocking Co., April 12, 1945; Scioto Co., June 9, 1943, and June 17, 1944.

E. divisa McA. was reported for Ohio incorrectly as *E. atrimucronata* Beamer.

E. iconica McA., Fig. 7, Hocking Co., April 11, 1945.

E. idonea Beamer (Jour. Kans. Ent. Soc. 8: 100, 1935) has precedence over *E. gargantua* Johnson (Ohio Biol. Surv. Bull. 31: 81, 1935) by eight days since the date of issue of the Journal was July 1, and of the Bulletin July 8. This is a common species on buckeye in Delaware Co., and occurs in Adams and Scioto Cos.

E. infinita Beamer, Fig. 11, Pickaway Co., Feb. 20, 1935, J. S. Caldwell; Knox Co., Sept. 17, Mary Auten; Ashland Co., Mary Auten; Hocking Co., April 11, 1945.

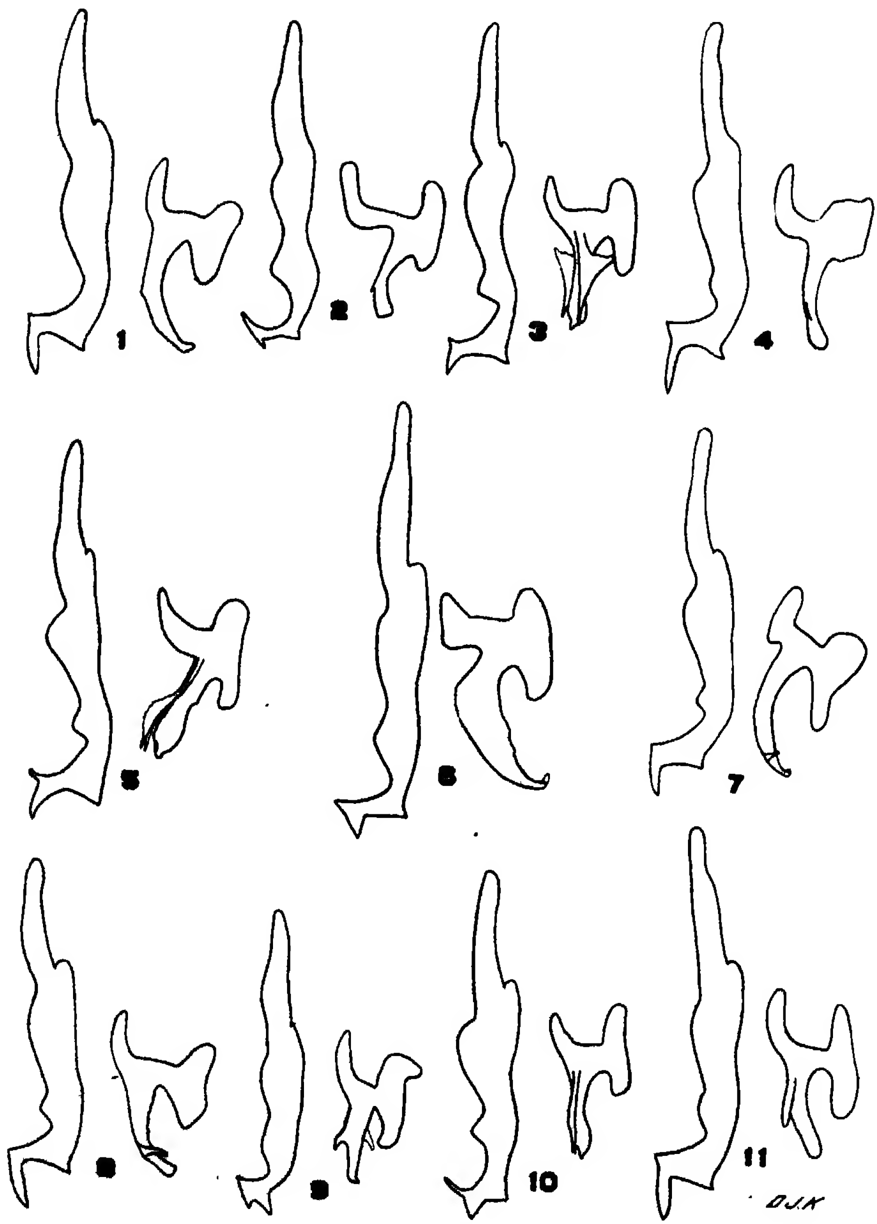
E. penelutea Beamer, Fig. 1, was reported from Ohio on the basis of one female specimen. A series has been taken throughout the season in Delaware and Hocking Cos.

E. perita Beamer, (Jour. Kans. Ent. Soc. 8: 100, 1935), Pickaway Co., April 5, 1934, J. S. Caldwell; Delaware Co., Aug. 27, 1942, Oct. 9, 1942, May 6, 1943, and Sept. 30, 1943. *E. extrema* Auten & Johnson (Ann. Ent. Soc. Am. 29: 64, 1936) is a synonym of this species.

Erythroneura praecisa n. sp.

Figure 10

General ground color white to semihyaline on elytra, where very little appears. Vertex with orange inverted V narrow at apex, and not touching eyes, even-sided, continued across pronotum as two slightly diverging orange vittae indented on outer margins at middle, and not touching anterior margin of pronotum; area between vittae darkened subcutaneously, basal angles of scutellum black, remainder yellow. Elytra extensively marked; clavus with broad vitta on basal two-thirds, dusky abdomen showing through gives outer third a dark cast, a narrow line along margin toward apex, usually lighter, a broad vitta on corium reaching crossveins, and a broad costal stripe, yellow translucent on plaque, crossveins partly red, dark spots above and below, except at base of M_2; R_1 and R_3 clouded, also base of M_4; lower part of M_4



FIGS. 1–11. Lateral view of style and aedeagus of *Erythroneura*. 1. *penelutea* Beamer. 2. *coarctata* Beamer. 3. *sagittata* Beamer. 4. *cotidiana* Beamer. 5. *alata* n. sp. 6. *victorialis* n. sp. 7. *iconica* McAtee. 8. *tenebrosa* n. sp. 9. *anomala* n. sp. 10. *praecisa* n. sp. 11. *infinita* Beamer.

and all of M_2 quite clear; below, head and legs sordid yellow, abdomen and mesonotum dark, dorsum dark.

Genitalia: Female, last ventral segment produced into truncate lobe on median third, pale, a few pale hairs on pygofer. Male: Style with small foot; heel a right angle, base short, straight, anterior point longer than posterior point and narrow, turned up, posterior point heavy, edges rough, as broad as base of foot, sides sharply converging, forming a little less than a right angle. Aedeagus almost straight in lateral view with rounded dorsal bulge toward flattened apex, a pair of narrow processes arises at anterior base and extends almost to tip, slightly serrate on ventral margin.

Length: 3 mm.

Holotype female, Hocking Co., June 1, 1938; allotype, April 28, 1934, J. S. Caldwell; paratypes August 31, 1944, and Sept. 16, 1943; paratypes, Great Smoky Mt. National Park, Tenn., June 14 and 21, 1942; and Indian Gap, Smoky Mts., Tenn., Sept. 8, 1939; Mary Auten.

In characters of genitalia close to *E. aspera* Beamer, but the foot of style is straight and aedeagus is narrower in lateral view.

E. sagittata Beamer, Fig. 3, Ashland Co., Sept. 23, Mary Auten; Delaware Co., Aug. 12, 1942, Sept. 9, 1943, Sept. 16, 1943, Oct. 3, 1943, and Oct. 9, 1942.

E. sincera Johnson has a pair of delicate processes just ventrad to base of shaft of aedeagus, sinuate, swollen slightly in middle, and extending to opening of duct. In this species as well as in *E. rubrotincta* Johnson, processes of aedeagus are often broken. Both species have been taken in Delaware Co., and *rubrotincta* has been taken also in Hocking, Monroe and Scioto Counties.

E. spearca Auten & Johnson, Hocking Co., April 17, 1938, and Oct. 17, 1941; Shawnee Forest, Scioto Co., June 9, 1943.

E. stolata McAtee, common in beech woods near Columbus. In some specimens a pair of fine lateral processes arises at base of aedeagus, separated from it, and extends almost parallel to shaft about one-third its length.

Erythroneura tenebrosa n. sp.

Figure 8

Ground color yellowish with narrow orange markings Inverted V of vertex with a tendency toward clover-shape, two lateral prongs extend toward upper inner corner of eyes; vittae of pronotum, two dashes remote from margins; basal angles of scutellum yellow, narrowly outlined on inner margins with orange, apex orange, narrow oblique vitta on clavus, one on middle of corium and faint streak along costal margin, three dark rounded spots before crossveins and apical cells clouded, inner two clearer. The dark dorsum showing through elytra in region of middle of clavus gives a characteristic banded appearance. Below, face sordid yellow, legs pale, area below beak dark, segments of venter of abdomen sordid yellow, genital segments pale, a dark stripe at base of dorsum of abdomen and some darkening below surface of scutellum and middle of pronotum.

Inner male genitalia: Style with medium stout foot, heel moderately projecting, base slightly curved, posterior point as long as base of foot, heavy, sometimes very broad, slightly curved in, blunt; anterior point about a right angle. Aedeagus in lateral view, curved dorsad at tip, apex laterally broadened and blunt, dorsal surface roughened, a pair of spines arises on ventral surface just before shaft opening and extends laterad, these spines taper evenly to apices and in lateral view extend about one-third their length beyond shaft.

Length: 3 mm.

A common species. Male holotype, Delaware Co., April 30, 1944, and paratypes, allotype Sept. 19, 1943, and paratypes, March 18, 1945, Sept. 9, 1943, April 26, 1944, March 25, 1945, and April 2, 1945; Hocking Co., June 28, May 1, 1938, April 11, 1945; Columbus, May 16, 1937, Mary Auten; and specimens previously placed with *E. autenae* Johnson: Knox Co., May 8, 1933, M. Auten & D. M. Johnson; Richland Co., Oct. 16, 1934, M. Auten; Allen Co., Aug. 19, 1934, D. M. Johnson.

Very similar in characters of inner male genitalia to *E. tenuispica* Beamer from which it is readily separated by its dark dorsum.

E. torva Beamer, Mohican St. Park, July 31, 1935, D. M. Johnson; and Delaware Co., April 2, 1945.

Erythroneura victorialis n sp.

Figure 6

Large, white with yellow markings except for those on clavus which are usually bright red. Head with broad indistinct inverted V not touching eyes, continued across pronotum as broad, faint, slightly diverging vittae; scutellum, basal angles and tip yellow; elytra, clavi with broad red vittae based on claval vein and filling a little more than apical third, outwardly and apically more translucent, shining, indistinct yellow with vittae on coria along vein and on costal margins, crossveins yellow, a few faint dusky spots before crossveins and apices hyaline. Below pale

Genitalia: Female, last ventral segment produced sharply on median third, in lobe slightly indented over ovipositor, median lobe equal in length to sides, ovipositor entirely pale, a row of white spines either side on pygofer. Male: Style with large, long foot, heel sharp, projecting, base straight, anterior projecting laterad, slightly smaller than heavy posterior point with which it joins in even line on outer edge. Posterior point meets base at more than right angle and is sharp-pointed. Aedeagus large, in lateral view swollen just below base, curves caudad, narrowed on outer half, toothed on ventral surface on widest basal portion, and dorsally below middle; apex bifid.

Length: 3.5 mm.

Taken from blueberry at 5,000 to 6,000 ft. in Great Smoky Mt. National Park, Tenn., holotype male, allotype and paratypes June 14, 1942, and paratypes June 21, 1942.

A bright red V on the clavi when elytra are closed, noticeable with unaided eye, caused the preparator to call this the "victory leafhopper." It is near in genital characters to *E nava* Beamer.

SEDIMENTARY ANALYSIS OF DRILL CUTTINGS FROM THE VANCE WELL, DELAWARE COUNTY, OHIO

WILLARD D. PYE[1]

The Chester L. Wise, et al, Herman E. Vance, No. 1, is located on Lot 11, Sec. 3, Orange Township, Delaware County, Ohio. This location is on the east side of the Olentangy River approximately 14 miles north of Columbus and 10 miles south of Delaware. Drilling commenced in September, 1934, and was completed in May, 1937, the entire hole being drilled by cable tool. The well started in the Ohio shale of Devonian age and bottomed at a total depth of 4291 feet in crystalline rocks of pre-Cambrian age. Despite the fact that the well was a dry hole, it is of importance because of the information it has yielded as to the subsurface stratigraphy of that part of Ohio. A detailed study of the drill cuttings from the Vance well has already been published.[2]

The total amount of material available for disaggregation and analysis was small, averaging only about 100 grams, and consisted of chips and sand brought up by the bailer from the indicated depths. Although some contamination of the cuttings undoubtedly occurred due to material being knocked off the upper walls of the hole during drilling operations, nevertheless, the analyses of the samples probably rather closely represent the formation being drilled.

The samples were taken at depths of 3435, 3440, and 3445 feet[3] and represent a Cambrian sandstone, possible just above the Jordan.[4] A gas-bearing brine was found at 3550 feet, just below the lowest sample.

The samples were all very uniform in appearance and consisted of a fine-grained, friable, fairly porous, yellowish-gray calcareous to dolomitic sandstone. The main cementing material was dolomitic calcite with some iron. In the coarse chips from the cuttings the carbonate is present as a cement binding the sand grains together; in the finer cuttings where the rock has been broken down into its individual mineral grain components, the carbonate cement is found as a fine powder. The original sand grains are rounded to well rounded and possess a fairly high degree of sphericity.

METHODS OF ANALYSIS AND DATA

Since it was obvious from microscopic examination that much of the "sand" was from the carbonate cement, one fraction of each sample was boiled for ten minutes in dilute hydrochloric acid to remove the carbonates, and in stannous chloride to clean the grains of iron oxide coatings so as to facilitate later mineral identification.

Table I gives the results of the mechanical analyses of both the untreated and acid treated samples. Sieving was by hand and lasted for 30 minutes. As this is longer than has recently become the standard practice for making sedimentary analyses, the final results probably were controlled to some extent by the largest opening in each sieve.

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[1]Now with the Texas Company, Box 167, U. S. A. C., Logan, Utah.

[2]W. Stout and C. A. Lamey, "Paleozoic and Pre-Cambrian Rocks of the Vance Well, Delaware County, Ohio," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, (1940), pp. 672–692.

[3]The samples were secured by Dr. G. D. Hubbard from Dr. W. Stout, State Geologist of Ohio. Acknowledgment is made to Messrs. A. J. Wallace and R. Mallory for supplemental information on the 3440 and 3445 foot samples.

[4]W. Stout and C. A. Lamey, *op. cit.*, pp. 672–692.

TABLE I

SIEVE ANALYSIS

DEPTH	3435 FEET	3440 FEET		3445 FEET	
Sieve Size (mm.)	Untreated %	Untreated %	Acid Treated %	Untreated %	Acid Treated %
1.000 - 0.495.	trace				
0.495 - 0 246.	2.3	6 4	2 4	2 1	3 3
0 246 - 0 124.	23 8	24 7	25 2	20 8	32 8
0.124 - 0 061.	37 5	42 1	53 7	48 3	51 2
0.061 - Pan...	36 4	26 8	18 7	28.8	12 7
Total	100 0	100 0	100 0	100 0	100 0
Mean Size.	0.085	0 096	0.096	0 086	0 108
Standard Deviation	0.56	0 55	0 62	0 61	0 62
Per cent sample into solution by acid.	64 1* 62.2†	..	60 9	.	41 3

*Different sample than the one sieved.
†Sample used for chemical analysis of cements.

TABLE II

PIPETTE ANALYSIS OF SAMPLE FROM 3445 FOOT DEPTH
(Untreated by acid)

Size (mm.)	Per Cent	Per Cent of Total Size Distribution
1/16 - 1/32.	40.9	11.8
1/32 - 1/64.	40.9	11 8
1/64 - 1/128	11 7	3 4
Less than 1/128.	6.5	1.8
Greater than 1/16 (from Table I)	...	71 2
Total..	100 0	100 0

TABLE III

MINERALOGY OF SAMPLE FROM 3440 FOOT DEPTH

Minerals	Untreated Sample %	Acid Treated Sample %
Iron stained quartz........	35	79
Opaques (Magnetite and Limonite)	5	10
Biotite........	1	4
Muscovite........	1	3
Garnet (pink and red)..	1	3
Hornblende......	1	1
Tourmaline........	1	..
Opaque and semi-opaque iron carbonates.	40	..
Calcite and Dolomite........	15	.

The material from the non-acid treated sample caught on the pan during the sieving of the 3445 foot depth sample was boiled in a solution carrying 0.5 grams of sodium carbonate and then diluted to 1000 cc. for pipette analysis. The results are presented in Table II. How much of this distribution was due to carbonate cement fragments was not determined.

The mineralogy of the samples is given below and is based upon both heavy mineral and thin section analyses.

Sample from 3435 foot depth: The cement binding the sand grains together consists of carbonate with minor amounts of iron oxide. Some post-depositional pyrite is also present. No silica cement is evident. Magnetite makes up fully fifty per cent of the heavy minerals; pyrite, limonite, and leucoxene make up minor amounts. The non-opaque heavy minerals are freshly broken (during drilling?) pink garnet, rounded topaz grains with many inclusions, and well rounded olive-green zircons. The dominant detrital light mineral is quartz, which may be clear or filled with inclusions. Acid feldspar is present but not common. The very abundant carbonate cement is all recrystallized and shows no evidence of a detrital origin.

Sample from 3440 foot depth: See Table III.

Sample from 3445 foot depth: Iron-stained quartz makes up most of the detrital minerals. Zircons, garnet, flourite, hematite, magnetite, leucoxene, and pyrite are present in small amounts. Magnetite makes up over 40 per cent of the heavy minerals with the other ore minerals making up most of the rest. Fragments of well crystallized carbonate cement are very common in the light fraction.

Chemical Analysis of Sample from 3435 Foot Depth: After a sample from the 3435 foot depth was leached with hydrochloric acid, it was found that a total of 62 per cent had gone into solution. This solution was analyzed for calcium, magnesium, and iron percentages. Although undoubtedly other elements for which no tests were made were present in minor amounts, the following were calculated to have made up all of the material that was dissolved by the acid:

$CaCO_3$	57%
$MgCO_3$	23%
$FeCO_3$ and Fe_2O_3	20%

(Note: Some of the iron probably came from small amounts of the magnetite and other iron minerals going into solution during the acid treatment.)

CONCLUSIONS

The formation is a highly dolomitic, calcareous, fine-grained sandstone with considerable iron carbonate and oxide. Silica cement is nil. The insoluble portion is dominantly made up of fine quartz sand with very little feldspar. Small amounts of heavy minerals are present. Of these, magnetite and the other opaque ore minerals predominate.

The degree of sorting coupled with the presence of well rounded zircon and topaz grains would indicate probably at least a second cycle of erosion for some of the sand. Not enough evidence was available to determine whether the sand was (1) deposited under aeolian conditions with later carbonate cementation by ground water, or (2) deposited under near shore, clear water conditions with no major streams entering the sea in the general vicinity, and a low lying, probably peneplaned, land-mass making up the coastal area. Either case would give a clean, well sorted, medium fine, calcareous sandstone deposit. The latter probably represents the conditions of deposition unless the formation is a combination of the two, being an aeolian sand reworked and deposited under the above outlined marine conditions.

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THE URINARY EXCRETION OF PENICILLIN AFTER INGESTION WITH AND WITHOUT ADJUVANTS AND FOLLOWING INTRAMUSCULAR INJECTION[1]

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In their classic paper Florey and co-workers (1) found that a large part of the antibacterial effectiveness of penicillin was lost when the drug was taken orally as compared with parenteral administration. This has since been confirmed by numerous investigators (2, 3, 4, 5, 6, 9, 11, 12, 13). It has generally been thought that successful administration of penicillin by mouth could be accomplished by protecting it from destruction by gastric acidity. Several studies have been reported in which attempts were made to circumvent this assumed mechanism of destruction either by neutralizing the gastric acidity by various antacid adjuvants taken with the penicillin or by encapsulating it in such a manner that it would not be released until it had reached the less acid or even slightly alkaline medium of the intestine.

Sodium bicarbonate ingested with or prior to penicillin (1, 5, 15) failed to protect most of the drug from destruction. Little and Lumb (8) reported that when penicillin mixed with raw egg white was ingested 10 minutes after taking sodium bicarbonate with milk the urinary excretion of the drug was comparable to that after a like dose injected intramuscularly; but Heatley (9) was unable to confirm their results, although he did find that the urinary excretion after taking the dose in egg white was more than double that when taken in water alone. Charney et al (5) gave penicillin orally with trisodium citrate, disodium phosphate, Amphojel (hydrous alumina), and milk with calcium carbonate, but only the trisodium citrate and the disodium phosphate in the fasting state increased the amount recoverable in the urine to only about one-third that which would have been excreted had the same dose been given intramuscularly (2, 22). The hydrous alumina gave an intermediate value when compared with the controls. In the absence of trisodium citrate only five per cent of the dose of penicillin taken after breakfast appeared in the urine whereas eleven per cent was excreted when the dose was taken with suitable amounts of trisodium citrate after breakfast. Even so this was only about one-fifth the amount which would have appeared in the urine had the dose been injected intramuscularly. Welch and co-workers (23) reported therapeutic blood levels of penicillin which were maintained for prolonged intervals of time after the ingestion of penicillin solutions to which suspensions of aluminum hydroxide or magnesium hydroxide were added dropwise. When 100,000 units thus treated with aluminum hydroxide were taken by eleven subjects the average recoverable in the urine during the next twenty-four hours was only

[1]This study is a contribution from the Departments of Medicine and Bacteriology of The Ohio State University under a fellowship sponsored by The Wm. S. Merrell Company and administered by The Ohio State University Research Foundation.

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13.6 per cent of the dose. These findings are supported by the findings of Charney et al (5) as well as by the present report. McDermott and co-workers (6) gave sufficiently large amounts of magnesium trisilicate over a period of three hours to change the pH of the stomach contents to about 8.0 before giving penicillin in water, in peanut oil, and in corn oil plus beeswax. The average urinary excretion during the next two hours was about twelve per cent in each case although there were indications that the oils delayed the excretion somewhat. György and his associates (7) reported mixed results in the clinical use of oral penicillin with trisodium citrate. With doses of penicillin comparable to those customarily given parenterally the combination was effective in the treatment of gonoccic urethritis in males as well as in a few other clinical conditions, but doses as high as 300,000 units (0.18 gm.[3]) given orally in combination with trisodium citrate brought about only temporary clinical improvement of gonoccic vaginitis in young girls even after three such courses of treatment whereas permanent cures were obtained when the same dose was administered intramuscularly. Krantz and co-workers (14) reported effective serum levels of penicillin after oral administration with basic aluminum aminoacetate. However, the effectiveness of this antacid is impossible to evaluate on the basis of their paper since the results of the control experiments where penicillin was taken by the same subjects without the antacid were not disclosed.

Florey et al (1) first suggested that the destruction of penicillin by gastric acidity might be prevented by using enteric-coated capsules but their attempts to use phenyl salicylate coated vehicles were unsuccessful. Burke (12) and his associates sealed penicillin in a capsule which was then surrounded by a second capsule that was treated by immersion in diluted formaldehyde for five seconds followed by 95 per cent alcohol for five minutes. The ingestion of 100,000 units (60 mg.[3]) in these capsules gave serum levels of penicillin comparable to those reported by others after the parenteral administration of 40,000 units. Libby (19) suggested the administration of penicillin by mouth suspended in digestible oils contained in enteric-coated capsules. In experiments in which the results of suitable controls were not reported, he found that therapeutic blood levels of penicillin were attainable by giving gelatin capsules containing 90,000 units of the calcium or sodium salt of the drug suspended in cottonseed oil. In view of the results reported by McDermott et al (6) it is probable that Libby would have found no therapeutic advantage to the use of the suspensions in oil had he tried either penicillin in capsules without the oil or simple aqueous solutions. (See under discussion of Table I). Recently Perlstein et al (21) gave penicillin calcium suspended in equal parts of lanolin and corn oil in gelatin capsules by mouth and found that the urinary excretion was thereby prolonged. However, the average total recovery was only about fifteen per cent or about one-fourth of what it would have been had the same amount been injected intramuscularly (2, 22).

In the following studies penicillin was taken by mouth in conjunction with various antacids and other adjuvants in attempts to decrease the destruction within the stomach and intestine so that the amounts recoverable in the urine might be made to approach or equal those recoverable after intramuscular administration. The results with a single subject are reported to avoid the confusion the data would present had the findings with several subjects been considered. It will be shown below that a remarkable constancy in the rate of excretion as well as the total amount of penicillin excreted occurred at different times in the same subject

[3]Since the international unit of penicillin has been defined as 0.6 microgram of the International Standard consisting of the pure crystalline sodium salt of penicillin G or II (17, 18), it has been proposed (16) that penicillin dosages might be expressed advantageously on the basis of the weight of the pure principle present in preparations now on the market rather than by the cumbersome unitage method. The situation is analogous to that proposed by Waksman (10) for expressing quantities of streptomycin used clinically.

under comparable experimental conditions. To avoid frequent, repeated venipunctures as well as the assay difficulties encountered in determining concentrations of penicillin in the blood, assays were carried out in triplicate by the Oxford Cup Method[4] on voided urines collected at standardized intervals throughout all of the experiments. This procedure permitted screening tests to be carried out very readily. The assumption on which it is based is supported by the work of Rantz and Kirby (15) who found that several-fold differences in the rate of urinary flow in certain subjects were not associated with variations in the plasma clearance of penicillin injected intravenously and that the rate of excretion was proportional to the plasma concentration.

Urinary Excretion after Ingestion of 100,000 Units with and without Adjuvants Compared with Intramuscular Injection

In Expt. 1, the contents of one vial of the sodium salt of penicillin (100,000 units) was dissolved in 20 ml. of sterile normal saline for injection deep intramuscularly at two sites on the thigh. The urine was collected one, two, three, four, six and eight hours later (Table I) and immediately diluted with cold one per cent phosphate buffer, pH 6.0, for assay. The total percentage of the dose recovered, 65.1, as well as the rate of excretion was comparable to the data in the literature (2, 22) after intramuscular administration in other subjects.

Expt. 2 was similarly carried out except that the penicillin was dissolved in only 10 ml. of sterile normal saline and the dose was injected into a single site. The very marked catharsis due to the simultaneous ingestion of five grams of U.S.P. magnesium oxide did not change the total amount excreted in the urine, 59.2 per cent, nor did it alter the rate curve significantly. This may be taken as evidence that the difference between an intramuscular dose and the amount recoverable in the urine is not due to elimination via the feces.

The average of the total amount excreted in the urine in the first two experiments is 62.1 per cent of the intramuscular dose. This value will serve through much of the discussion as a reference with which values obtained after oral administration may be compared.

Expt. 3. When 100,000 units (60 mg.[3]) were taken on an overnight fasting stomach, 11.4 per cent of the dose was excreted in the urine in the first six hours. The results of this experiment wherein a very crude calcium salt of penicillin extracted from a surface culture of a strain of *Penicillium notatum*[5] was ingested should be compared with the 11.2 per cent recovered in Expt. 6 where the same unitage as a highly refined sodium salt of penicillin extracted from a submerged culture of the mold was taken orally. Obviously there was no difference.

The average of the total amount recovered in the urine in Expts. 3 and 6 was 11.3 per cent. Comparison of this value with the average of 62.1 per cent after intramuscular injection reveals that only 18.2 per cent as much appears in the urine after ingestion on a *fasting stomach* as after intramuscular injection in the subject used. In other words five times as much would be required for oral administration *in the fasting state.*

The situation when penicillin was administered orally on a non-fasting stomach in the same subject is illustrated by the data for Expt. 12 where the total excretion was 4.7 per cent of the dose. This means that, based on these data, the subject used would have to ingest thirteen times the intramuscular dose on a *non-fasting stomach* (compare with Expt. 108).

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[4] I am indebted to Marguerite M. Sullivan for these assays.

[5] Obtained from the Northern Regional Research Laboratory.

TABLE I

URINARY EXCRETION OF PENICILLIN AFTER ADMINISTRATION OF 100,000 UNITS

EXPT. No.	ROUTE	DATE	CONDITIONS UNDER WHICH PENICILLIN WAS ADMINISTERED	PER CENT OF DOSE EXCRETED IN THE INTERVALS (Hrs.)						TOTAL % OF DOSE RECOVERED
				0-1	1-2	2-3	3-4	4-6[4]	6-8	
1	I-M[1]	3/22/45	In normal saline, non-fasting...	39 7	15.6	5 1	2.8	1 6	0 3	65 1
2	I-M[1]	3/23/45	In normal saline, non-fasting; 5.0 gram MgO taken at same time in 200 ml. tap water. Marked catharsis when each specimen was collected	28.1	17.8	8 0	2 3	2 4	0.6	59.2
3	Oral[2]	12/6/44	In 200 ml. water on an overnight fasting stomach . .. . , ...	4 7	3 5	1 6	1 0	0 6		11 4
4	Oral[2]	12/8/44	Suspended in 75 ml. U.S P. Cottonseed oil followed by 200 ml. tap water on an overnight fasting stomach.	4 5	4 2	1 7	0 7	0.5	.	11 6
5	Oral[2]	12/12/44	1 mg. Atropine followed 10 minutes later by the penicillin dissolved in 200 ml. cold tap water on an overnight fasting stomach	3 5	3.1	2.5	2 1	1.7[5]	0 4	13 3
6	Oral[1]	3/27/45	In 350 ml. tap water on an overnight fasting stomach	4 7	3 2	1 3	1 1	0 9		11 2
7	Oral[1]	4/4/45	In water on an overnight fasting stomach, 10 minutes after taking 5 gms. Al(OH)[5]3 suspended in water .... , ...	5 3	4 0	1 5	0 8	0 6		12 2
8	Oral[1]	4/6/45	In water on an overnight fasting stomach followed immediately by 500 ml. tap water at 4° C. Another 200 ml. at 4° C. was drunk when first urine specimen was collected..	3 9	3 8	1 2	1 3	1.1	0 2	11 5
9	Oral[1]	4/17/45	Dissolved in whites of 2 eggs 10 minutes following 10 gms. of $NaHCO_3$ dissolved in ½ pint of homogenized milk on an overnight fasting stomach	1.0	5.2	2 3	1.0	2 1	.....	11.6
10	Oral[1]	5/14/45	In water on an overnight fasting stomach 10 minutes after taking 20 gms. of powdered egg white dissolved and suspended in about 400 ml. of tap water. .	3.5	2.6	2.1	1 5	1.1	0.1	10.9
11	Oral[1]	5/9/45	Dissolved in egg-nog containing 3 egg whites, milk, sugar and vanilla immediately after a breakfast consisting of bacon, egg, toast with butter and hot chocolate made with milk	1.5	3 1	1.3	0 9	1 2	0 2	8 2
12	Oral[1]	5/7/45	In water 40 minutes after breakfast consisting of orange juice, toast and butter, poached egg, and dry cereal with milk and sugar........	1.3	1 6	0.9	0 6	0 4		4 7
13	Oral[1]	4/10/45	In water on an overnight fasting stomach 10 minutes following 25 gms. of Wilson Granular Concentrated Mucin washed down with 250 ml. of tap water..	2.4	1 7	0.7	0 3	0 2	.	5 3
14	Oral[1]	5/11/45	Dissolved in 400 ml. water containing 20 gms. glycine on an overnight fasting stomach	3.4	3.7	2 0	0 9	0 6	0 1	9 7
15	Oral[4]	5/16/45	In water immediately following 5 gms. activated charcoal, Merck, suspended in 300 ml. water on an overnight fasting stomach	0.2	0 2	0.2	0.1	0.1	. . .	0.8
16	Oral[1]	3/28/45	In 400 ml. water containing 2 gms. tri-sodium citrate on an overnight fasting stomach	7.0	7.2	2.4	1 4	0 8	. . .	18.8
17	Oral[1]	6/18/45	In water on overnight fasting stomach followed immediately by a solution of 5.0 gms. ferric ammonium citrate in about 300 ml. tap water	0.7	3.0	2.4	1.1	0.8	0.3	8.3

TABLE I—(*Continued*)

Expt. No.	Route	Date	Conditions under which Penicillin was Administered	Per Cent of Dose Excreted in the Intervals (Hrs.)						Total % of Dose Recovered
				0–1	1–2	2–3	4–5	4–6[4]	6–8	
18	Oral[1]	6/14/45	In water on overnight fasting stomach followed immediately by a solution of 5.0 gms. d-glutamic acid adjusted to pH = 8.0 with NH_4OH in about 300 ml. tap water	2.6	5.2	2.1	0.9	1.0	0.1	11.9
19	Oral[1]	6/15/45	In water on overnight fasting stomach together with an elixir of ammonium citrate[6] calculated to contain 5.0 gms. of the salt in about 250 ml. tap water......	3.4	3.1	2.1	1.2	1.0	0.1	10.9
20	Oral[1]	6/19/45	In water on overnight fasting stomach followed immediately by 5.0 gms. of diammonium acid citrate in solution in about 300 ml. tap water.. .	2.0	2.3	0.8	0.4	0.5	0.6	6.6
21	Oral[1]	6/21/45	In water on overnight fasting stomach followed immediately by a suspension of 20.0 gms. of casein in about 500 ml. of tap water.	3.6	1.5	1.4	0.8	0.8	0.2	8.3
22	Oral[1]	6/23/45	In water on overnight fasting stomach followed immediately by a suspension of 20.0 gms. of zein in about 400 ml. tap water	2.9	3.3	1.7	1.0	0.9	0.2	10.2
23	Oral[1]	6/27/45	One vial dissolved in 20 ml. water, 30 ml hydrous alumina (Creamalin, Liquid) slowly stirred in. Immediately drunk on overnight fasting stomach. .	5.3	5.4	2.3	0.9	0.6	.	14.5

[1]Penicillin Sodium, deep culture.
[2]Calcium salt containing 54.5 units/mg. surface culture.
[3]Estimated value.
[4]Regular lunch eaten in this interval.
[5]Kindly supplied by the Wm. S. Merrell Co.
[6]13.3 ml. of a solution of 12 gm./fl. oz. of ammonium citrate kindly supplied by the Wm. S. Merrell Co.

Expt. 4. It was felt that suspending the penicillin in a digestible oil might protect it from the destruction by the gastric juice while permitting its release for absorption in the duodenum and jejunum. The results of this experiment, 11.6 per cent, indicate that there was no therapeutic advantage to be gained from suspending penicillin in cottonseed oil for ingestion over giving it in simple aqueous solution. This is in contrast to the inferences of Libby's paper (19) in which the results of suitable control experiments were not reported.

Expt. 5. These data reveal only a slight advantage to the use of atropine with a view to decreasing the destruction by gastric juice of penicillin taken orally.

Expt. 6. Discussed under Expt. 3 above.

Expt. 7. U. S. P. aluminum hydroxide, dried, ingested with the penicillin increased the amount recoverable in the urine slightly to 12.2 per cent. In Expt. 23, 30 ml. of a suspension of approximately 5.5 per cent aluminum hydroxide (Creamalin, Liquid) was slowly stirred dropwise into 100,000 units of penicillin dissolved in 20 ml. of distilled water and immediately drunk on an overnight fasting stomach. This method of mixing increased the amount recoverable in the urine during the first six hours to 14.5 per cent. According to these data four times as much of the penicillin treated in this way would have to be ingested on a fasting stomach instead of five times the dose in simple aqueous solution required over the intramuscular route. The method of preparation of the "modified" penicillin was essentially that of Welch *et al* (23) and the amount of the ingested dose recoverable in the urine was the same as they reported.

EXPT. 8. Chilling the stomach with large volumes of cold water simultaneously with the ingestion of the penicillin did not change the amount excreted in the urine.

EXPT. 9. This work was done to try to duplicate the findings of Little and Lumb (8) who reported that sodium bicarbonate in milk followed by penicillin dissolved in raw egg white resulted in urine levels of penicillin comparable to those following similar doses administered intramuscularly. Heatley (9) was unable to confirm this and obviously the data in Table I do not support it in the case of the subject used but show instead that the excretion was the same as would have occurred had the same dose been taken on a fasting stomach without the alkali and egg white.

EXPT. 10. This work was designed to see whether egg white alone would be as effective as with sodium bicarbonate and the data showed that this was the case. This suggests then that by giving penicillin with egg white it is unnecessary to keep the individual in the fasting state if five times as much penicillin is given as would be required by intramuscular injection instead of the use of thirteen times as much in the non-fasting state.

EXPT. 11. In order to test the protective action of egg white further, penicillin was given in an egg-nog containing the whites of three eggs on a non-fasting stomach. The total recovered in the urine was 8.2 per cent compared with 4.7 per cent in Expt. 12 where the same dose of penicillin was taken without egg white on a non-fasting stomach. This means that eight instead of thirteen times as much would be required to bring the urinary excretion levels up to the values attained by intramuscular injection.

Little and Lumb (8) attribute the protective action of egg white to its sulfur content. The acid buffering capacity of the egg white protein itself as well as its digestion products as they are gradually and continuously split off by the action of acid-pepsin might be important factors in the protective action.

EXPT. 12. Discussed under Expts. 3 and 11.

EXPT. 13. It is generally thought that gastric mucin elaborated by cells lining the stomach protect the mucosa from the action of the acid-pepsin. However, 25 grams of a concentrated mucin preparation swallowed and washed into the stomach with tap water followed ten minutes later by 100,000 units of penicillin in water was ineffective.

EXPT. 14. The buffering capacity of various substances with respect to 0.100 N HCl was determined as shown in Table II. It will be noted that only five grams of glycine prevented the pH from dropping below 3.1 when 150 ml. of the acid was added. Since previous experiments[6] had shown that penicillin was much more stable at pH 3.1 than would have been the case at the usual pH of gastric juice (about 1.8 or less), 20 grams of glycine dissolved in water was drunk on an overnight fasting stomach followed immediately by 100,000 units of penicillin in water. The resulting total urinary excretion was only 9.7 per cent.

EXPT. 15. Data in Table II show that acid is taken up by an activated carbon to a considerable degree. Since penicillin is readily absorbed by activated carbon it was decided to take penicillin orally with it to see whether the penicillin so absorbed would be protected from the action of the gastric juice with the thought that it might be eluted from the carbon for absorption in the duodenum and jejunum. Less than one per cent of the dose was recovered in the urine when five grams of Merck's activated carbon was used.

EXPT. 16. This experiment was undertaken to determine whether similar results could be obtained with the subject under study as those reported by Charney, *et al* (5). The data confirm their findings. When five grams of trisodium

[6]Unpublished data.

citrate were ingested on an overnight fasting stomach with 100,000 units of penicillin, 18.8 per cent of the dose was recovered in the urine. This is 30 per cent of the recovery after intramuscular administration and 166 per cent of the amount recoverable in the urine after ingestion under similar conditions except that no sodium citrate was taken simultaneously.

EXPT. 17. A heavy dose of ferric ammonium citrate proved to be of no advantage. It was taken with the thought of combining the oxidizing properties of the ferric iron with the acid buffering capacity of ammonium citrate. An oxidizing agent was used in an attempt to prevent the inactivation of penicillin in the strongly reducing medium of the upper intestine since Abraham and Chain (24) stated that penicillin was inactivated by such reducing agents as $NaHSO_3$ and $Na_2S_2O_4$ among others as well as by the primary alcohols and Cavillito and Bailey (25) and others (26, 27) reported that cysteine readily inactivated penicillin.

TABLE II

IN THE FOLLOWING EXPERIMENTS 5.0 GMS. OF EACH REAGENT WERE DISSOLVED OR SUSPENDED IN ABOUT 75 ML. OF DISTILLED WATER AND STIRRED VIGOROUSLY DURING THE ADDITION OF 0.100 N HCl WHILE NOTING CHANGES IN pH WITH A GLASS ELECTRODE

ml. 0.100 N HCl	Trisodium Citrate	Glycerine	Egg Albumin Powder	Merck Activated Charcoal	Ammonium[1] Glutamate Solution	Ferric Ammonium Citrate	Di-ammonium Acid Citrate	Ammonium[2] Citrate Solution
	pH	pH	pH	pH	pH	pH	pH	pH
0	8 6	5 8	7 1	6 4	7 8	6 4	5 6	5 0
1	7 7	5 1	6 8	5 9	7 7	6 3	5 6	5 0
2	7 3	4 8	6 5	5 6	7 6	6 2	5 6	5 0
3	7 2	4 7	6 3	5 3	7 5	6 1	5 6	5 0
4	7 1	4 5	6 1	5 1	7 3	6 0	5 6	5 0
5	7 0	4 4	6 0	4 8	7 1	5 9	5 6	5 0
10	6 7	4 2	5 3	3 9	6 4	5 3	5 6	5 0
15	6.5	4 2	4 8	3 4	6 0	4 8	5 6	5 0
20	6 4	4 0	4 3	3 0	5 7	4 5	5 6	4 9
25	6 3	4 0	3 9	2 7	5 6	4 2	5 6	4 8
30	6 2	3 9	3 6	2 5		3 8	5 6	
40	6 1	3 7	3 1	2 3		3 2	5 5	
50	6 0	3 6	2 8	2 2	5 1	2 8	5 4	4 7
100	5 5	3 3	2 0	2 2	4 6	2 2	5 0	4 4
150	5 0	3 1	1 8	1 7	4 4		4 7	4 1
200	4 3				4 1		4 4	3 9
250					3 5		4 1	3 6
300							3 8	3 3

[1] 5.0 gms. d-glutamic acid suspended in water, pH = 3.3. Solution affected by addition of 5.5 ml. of concentrated NH_4OH. Final pH = 7.8.

[2] 13.3 ml. of a solution of 12 gm./fl. oz. of ammonium citrate kindly supplied by the Wm. S. Merrell Co.

EXPT. 18. Only an insignificant increase to 11.9 per cent excreted in the urine resulted from the simultaneous ingestion of ammonium glutamate over the 11.3 per cent recovery when the simple aqueous solution was drunk.

EXPT. 19. An elixir of ammonium citrate proved to be of no particular advantage in spite of its great *in vitro* buffering capacity as shown in Table II.

EXPT. 20. When five grams of diammonium acid citrate dissolved in water were drunk immediately following an aqueous solution of 100,000 units of penicillin on an overnight fasting stomach, only 6.6 per cent of the dose was excreted in the urine. This was only about one-third of the recovery resulting when the same amount of trisodium citrate was simultaneously ingested (compare with Expt. 16).

EXPT. 21. A heavy suspension of casein was found to have a protective capacity mid-way between that of powdered egg white and the non-fasting state (compare Expts. 10 and 12).

EXPT. 22. A heavy suspension of zein was tried because this protein is quite insoluble in water and it was felt that it might resist digestion in the stomach for some time and thus exert a protein acid-buffering protective capacity longer than in the case of soluble proteins. Compared with Expt. 10 it was found to be almost as efficacious as powered egg white.

URINARY EXCRETION AFTER INGESTION OF 43,250 UNITS WITH MAGNESIUM TRISILICATE AND OTHER ADJUVANTS

The penicillin used in compiling the data in Table III was in the form of tablets made up with magnesium trisilicate[7] to contain 4,325 units each. Ten of the tablets were taken by mouth for each of the experiments under the conditions described in the table.

TABLE III

URINARY EXCRETION OF PENICILLIN AFTER ORAL ADMINISTRATION OF 43,250 UNITS OF TABLETS MADE UP WITH MAGNESIUM TRISILICATE[1]

EXPT. No.	DATE	CONDITIONS UNDER WHICH PENICILLIN WAS ADMINISTERED	PER CENT OF DOSE EXCRETED IN THE INTERVALS (HRS.)					TOTAL % OF DOSE RECOVERED
			0–1	1–2	2–3	3–4	4–6[2]	
101	1/31/45	With 300 ml. tap water on an overnight fasting stomach	3.7	3.3	1.8	1.0	1.0	10.8
102	2/2/45	In tap water on an overnight fasting stomach followed immediately by 3 gms. U.S.P. sodium benzoate dissolved in tap water	1.1	2.3	1.1	0.6	0.4	5
103	2/7/45	In tap water on an overnight fasting stomach followed immediately by 0.7 mg. atropine and 75 mg. phenobarbital	2.5	2.6	1.9	1.5	0.9	9.4
104	2/9/45	Same as No. 103 except the penicillin was taken 45 minutes after the atropine and phenobarbital were ingested.	1.9	2.2	.8	1.2	0.9	9.0
105	2/12/45	In tap water on an overnight fasting stomach followed by a suspension of 5 gms. of magnesium trisilicate in 350 ml. of tap water	1.2	2.5	0.9	0.3	0.2	5.1
106	2/14/45	In tap water on an overnight fasting stomach followed immediately by a suspension of 5 gms. of magnesium oxide in 400 ml. of tap water	0.9	0.6	0.1	0	0	1.6
107	2/16/45	In tap water on an overnight fasting stomach followed immediately by 5 Creamalin tablets (hydrous alumina) which had soaked overnight in water	3.6	2.9	1.3	0.6	0.4	8.8
108	2/24/45	With 1 pint of homogenized milk 1 hour after breakfast consisting of bacon, 1 egg, toast and butter, hot chocolate made with milk, and half grapefruit	0.2	1.0	1.0	0.4	0.5	3.1

[1]Kindly supplied by the Wm. S. Merrell Co.
[2]Regular lunch eaten in this interval.

EXPT. 101. 43,250 units were taken on an overnight fasting stomach. The 10.8 per cent total of the dose excreted in the urine compared closely with the amounts recoverable when 100,000 units were ingested (see discussion of Expts. 3 and 6). Obviously the incorporation of magnesium trisilicate with the penicillin in the tablet was not advantageous.

EXPT. 102. It is well known that the ingestion of sodium benzoate results in conjugation with glycine in the liver to form hippuric acid which is then excreted in the urine. Beyer et al (28) showed that the simultaneous intravenous administration of p-amino-hippuric acid with penicillin resulted in greatly prolonging the urinary excretion of the drug with attendant increased blood levels for long

[7]Obtained from the Wm. S. Merrell Co.

intervals of time. It was thought that the ingestion of sodium benzoate with penicillin might result in the delayed excretion of the latter because of preferential excretion by the kidneys of the hippuric acid formed in the liver from the sodium benzoate. Neither the total amount recoverable nor the rate of excretion data support the hypothesis.

Expts. 103 and 104. These data demonstrate that destruction by the gastric juice of penicillin taken orally was not significantly altered either by taking the drug simultaneously with atropine or by taking it after atropine at a sufficient interval for any maximal effect of the atropine on the secretion of gastric juice to have occurred.

Expt. 105. These data show that the simultaneous ingestion of a large dose of magnesium trisilicate with penicillin had a deleterious effect on the amount of antibiotic activity recoverable in the urine. Possibly the magnesium trisilicate absorbed the penicillin and did not release it, or it may greatly prolong the emptying-time of the stomach similar to the view held by some concerning the action of sodium bicarbonate (13).

Expt. 106. When five grams of magnesium oxide were taken as an antacid simultaneously with the tablets containing the penicillin, marked catharsis resulted. The data show that the penicillin may have been washed out of the stomach and intestine in the voluminous, watery stools. This was true both with respect to the total activity recoverable as well as the rate at which penicillin appeared in the urine. If the interpretation that the penicillin was washed out in the feces be valid, then the question arises as to whether the absorption from the gut into the blood stream normally may be only a slow process.

Expt. 107. The results of this experiment are at variance with those of Expts. 7 and 23 in that hydrated alumina (Creamalin, Tablets) were not effective in preventing the destruction of penicillin taken orally under the conditions of the experiment.

Expt. 108. Here the penicillin was taken about an hour after a meal and the data confirm the results of Expt. 12 (Table I). The recovery was only 3.1 per cent. When this is compared with the results of Expt. 101 it is seen that less than thirty per cent of the recovery when the drug was taken on a fasting stomach was obtained. These data mean that about twenty times the intramuscular dose would be required on a non-fasting stomach to bring the urinary excretion to the same level (compare with Expts. 3 and 11).

Discussion

The data in these studies show that the maximal amount of oral penicillin recoverable in the urine was less than one-third of the antibiotic activity excreted in the urine after the same dose was injected intramuscularly. That this was true in spite of the simultaneous ingestion of large amounts of various antacids leads to the thought that gastric acidity is not solely responsible for the destruction of ingested penicillin. Rammelkamp and Helm (3) found that only 22.7 and 39.6 per cent of the ingested dose appeared in the urine of two achlorhydric pernicious anemia patients. Previous experiments[8] have shown that sixty-six per cent of the original activity was retained for twenty-four hours at 37° C. at pH 5 *in vitro*. In Table II it is seen that sufficient amounts of trisodium citrate and diammonium acid citrate were ingested with penicillin to have maintained this pH in the presence of 150 ml. and 100 ml. of one-tenth normal hydrochloric acid respectively. In spite of this similar *in vitro* buffering capacity, the data in Table I (Expts. 16 and 20) demonstrate that there was a three-fold difference in

[8]Unpublished data.

antibiotic activity in the urine. Since penicillin was taken with these buffers on a fasting stomach and was not followed by food, it is probable that little if any free hydrochloric acid was present or appeared soon after ingestion took place. Further, the bitter and nauseating concoctions probably would have inhibited gastric secretion for some time. Moreover, the data show that more than one-third of the total amount excreted appeared in the urine during the first hour when, according to the data of Bergeim (30), an average of only 0.07 per cent of free hydrochloric acid appears in the gastric contents during the first forty-five minutes after a meal.

It is thought that the decreased efficacy of oral penicillin, aside from that which does occur due to destruction previously by gastric acidity, may be due in large part to inactivation in the liver when the penicillin is absorbed into and carried by the portal system directly to that organ from the gastro-intestinal tract. The critical experiments of Florey et al (1) on this point merit repetition since their results were not conclusive in view of the small amounts of the drug which they had available for use in such experiments at that time. Recently Perlstein et al (20) presented evidence that the hypothesis could be correct and that the penicillin may be inactivated in the liver by coupling with glucuronic acid similar to the inactivation of aromatic acids, phenols and alcohols by conjugation with this acid (29). No suitable adjuvant which might prevent such conjugation is foreseen.

Conclusions and Summary

Bearing in mind all of the advantages and limitations imposed by the use of a single subject, the data presented in this report seem to justify the following conclusions with respect to that subject.

1. Five times as much penicillin is required to be ingested *on a fasting stomach* to give the same excretion of penicillin via the kidneys as by intramuscular injection in the subject used.

2. Thirteen to twenty times as much is required orally *in the non-fasting state.*

3. There is no difference between the penicillin extracted from surface cultures of the mold compared with submerged cultures with respect to destruction when taken orally as judged by recovery of antibiotic activity in the urine.

4. The same proportion of the antibiotic activity is recoverable in the urine when the same dose (based on antibiotic activity) of a very crude calcium salt of penicillin is ingested compared with a highly refined sodium salt of the drug.

5. There is no therapeutic advantage to the oral administration of penicillin suspended in cotton-seed oil over a simple aqueous solution of the drug.

6. Atropine taken simultaneously with oral penicillin or forty-five minutes before the antibiotic was ingested did not increase the proportion excreted in the urine over that recoverable when atropine was not taken.

7. Aluminum hydroxide taken with penicillin either did not change or increased only slightly (depending on the method of mixing) the amount of antibiotic activity recoverable in the urine. At best four times as much penicillin would have had to have been taken with the aluminum hydroxide on a fasting stomach to have given the same amount of excretion via the kidneys as by the intramuscular route of administration of penicillin.

8. Ferric ammonium citrate, ammonium glutamate, elixir of ammonium citrate, diammonium acid citrate, magnesium trisilicate, magnesium oxide, glycine, activated carbon, sodium benzoate, concentrated mucin, casein, and zein when ingested simultaneously with penicillin on a fasting stomach either decreased or did not alter the proportion of the antibiotic activity recoverable in the urine compared with oral administration in tap water.

9. The ingestion of five grams of trisodium citrate with penicillin increased the amount of the dose recoverable in the urine by sixty-six per cent over that recoverable without the salt but the amount in the urine was still only thirty per cent of that recoverable had the same dose been given intramuscularly.

10. Ingestion of penicillin with raw egg-white with or without sodium bicarbonate resulted in the same proportion of the penicillin being excreted in the urine as after taking the same dose with tap water on a fasting stomach.

11. Chilling the stomach with large volumes of cold water did not increase the amount of orally administered penicillin which appeared in the urine.

12. The capacity for the increased destruction of penicillin taken with food compared with oral administration in the fasting state persisted for several hours after the food was eaten.

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The Dice of Destiny

The Dice of Destiny is a timely book. These are days when some scientists must leave the ivory lab long enough to present in clear and simple language to the many the facts known to the few. Knowledge and good-will are both necessary if man is to control his destiny for the common good. Neither alone will suffice.

Dr. Rife, for many years a specialist in the field of human heredity, has made a notable contribution to a better understanding of human nature in this little book. He has chosen wisely in title, in content, and in method of presentation. The book is to be recommended as much for omission of subject material as for what is included. Without attempting to chart a course for the unsuspecting reader through the tortuous channels of modern genetics, the author has presented in compact form a wealth of pertinent facts on inherited variations as found in individuals, families, and races. He has dealt largely, though not exclusively, with genetic alternatives widely spread in human populations rather than with rare inherited abnormalities.

The first chapter begins with: "Take a piece of paper from the envelope on the back inside cover of the book, put it in your mouth and make a paper wad of it. Does it taste bitter?" This is perhaps the first time that an author has invited his reading public literally to taste a book. Even though that initial taste proves bitter, as it will to about 70% of readers, the reviewer will venture that few will stop until they have fed well on the substantial meal which follows.

A concise discussion of the inheritance of taste, blood groups, hair, skin and eye color, sex and sex-linked characters, twinning, finger-prints, handedness, mental capacity, and special abilities is included. Racial variations in these and other traits are considered. A sound presentation of the relative roles of heredity and environment, of eugenic methods and their probable results, and of racial and individual variations, gives the reader a background for understanding the problems of human nature. In the closing chapter, "Genes and Democracy," current fallacies about race are exposed, a glimpse of possible scientific advances leading to improved environment is given, and an equality of opportunity for all is urged.

Unfortunately the book, otherwise attractive in format, is marred by frequent typographical errors. It is to be hoped that these will be corrected in a second printing, as some of them will prove confusing to the general reader.—*Warren P. Spencer.*

The Dice of Destiny, An Introduction to Heredity and Racial Variations, by David C. Rife. 163 pages, 23 figures and 14 tables. Long's College Book Co., Columbus, Ohio, 1945. $1.75.

STUDIES IN LABORATORY REARING OF ANOPHELES QUADRIMACULATUS SAY[1]

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Since a constant supply of healthy, vigorous, adult mosquitoes was needed for use in various studies being made on insect repellents, laboratory rearing of *Aedes aegypti* and *Anopheles quadrimaculatus* was initiated. No difficulties were encountered in rearing *Aedes* but the same cannot be said for *Anopheles*, consequently this paper deals only with the latter species.

A generous supply of *Anopheles quadrimaculatus* eggs was obtained from the U. S. Department of Agriculture, Bureau of Entomology Laboratory at Orlando, Florida, in November, 1943. The method of rearing followed at that time was obtained from notes made by Dr. C. E. Venard at Orlando and from the publication by Crowell (1940). In following these methods certain difficulties were encountered in rearing the larvae through the four instars. It was learned that other laboratories were having similar rearing troubles. This paper is written to report several modifications of the above mentioned techniques with the hope that the suggestions offered will be of value to those now engaged in similar work and helpful to those who may later become interested in such activity.

The rearing room was 11 x 6½ feet with a ceiling 10 feet high and lighted by a fluorescent lamp containing two 40-watt white tubes, which was on only during the day. The temperature was maintained at approximately 80° F. and the relative humidity varied from 40 to 70 per cent, but most of the time it was very near 50 per cent.

ADULTS.—The adults for egg-laying were maintained in a 16 mesh screened thirty-inch cubical sleeve cage. Water was available to the mosquitoes in the oviposition pan. As a source of food each cage was supplied daily with a piece of absorbent cotton approximately one inch square saturated with a 5 per cent honey solution in water and in addition a blood meal was furnished by allowing them to feed from the clipped belly of an immobilized rabbit introduced into the cage for one-half hour. The rack for holding the rabbit was similar to that used by Campbell, Barnhart and Hutzel (1941) with the exception that the bottom, sides and ends were completely enclosed. This eliminated all hiding places and very few mosquitoes escaped into the room when the apparatus was removed from the cage. Another precaution taken to prevent escape was the use of a rubber tube from a compressed air line to blow the mosquitoes off the rack and away from the sleeve as the rabbit was being withdrawn. It was found that the rabbit lay more quietly if its head was not exposed to the mosquitoes in the cage, consequently the sleeve of the cage was pinned around the neck and the head remained outside.

The population was maintained by placing jars containing pupae in the stock cage. A screen wire cone with 1½ inch opening at the top was placed over each jar to allow the emerging adults to escape into the cage, but prevent egg-laying adults from ovipositing in them. On alternate days a 5" x 5" cylindrical screen wire cage with a 1" x 4" opening and a sliding celluloid lid was placed over a jar where emergence was underway and the adults thus obtained were placed on a shelf to give a series of cages of "dated" mosquitoes for use in laboratory tests.

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[1]The work described in this paper was done under a contract recommended by The Committee on Medical Research, between The Office of Scientific Research and Development and the Ohio State University Research Foundation.

Eggs.—For oviposition a white enameled pan 10 inches in diameter and 2¾ inches deep containing water to a depth of 1 to 2 inches was placed in the stock cage daily. On the following day it was removed and all adults picked from the surface with a pair of forceps. The water was siphoned off by means of a device made from a block of wood ¾" in thickness, and a glass tube with dimensions as shown in Figure 1. The pan was set on a gently sloping surface so that the water

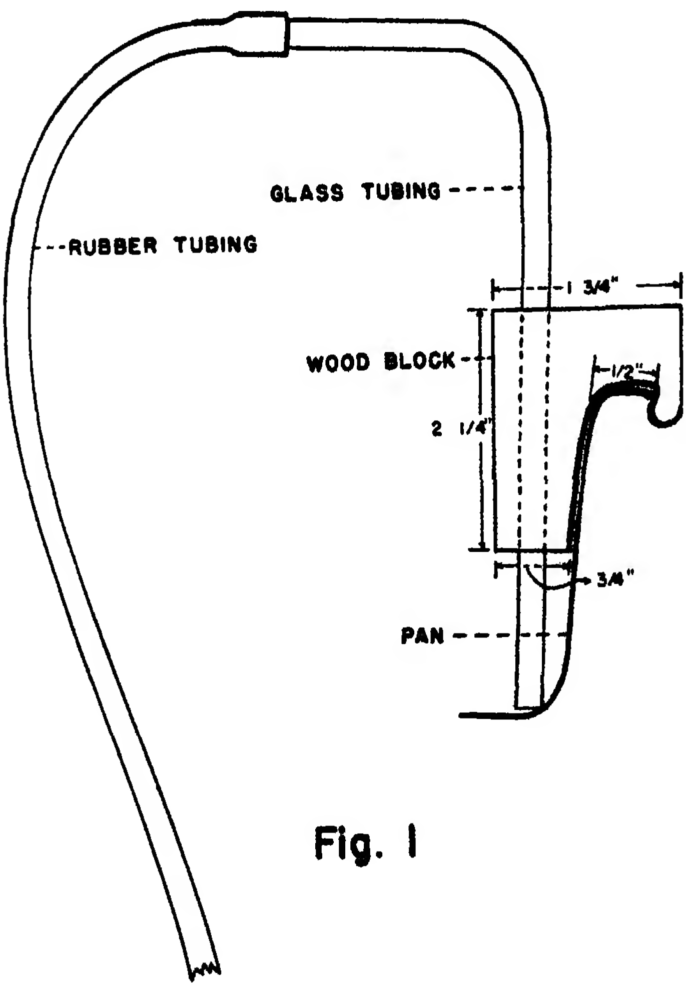

Fig. 1

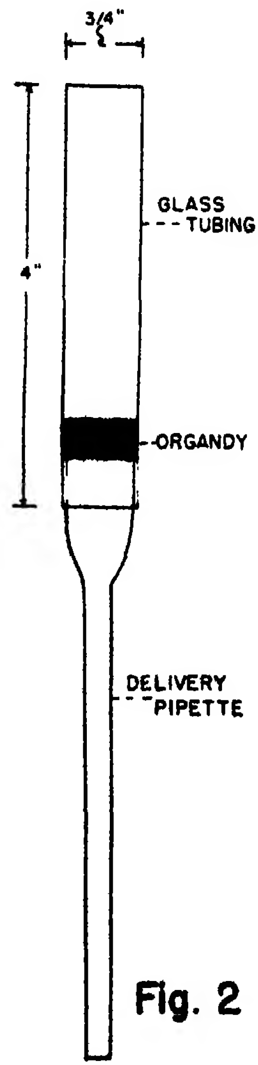

Fig. 2

Figs. 1 and 2. Devices for concentrating Anopheline eggs.

would run to the lower side. The flow from the siphon was stopped just as the floating eggs near the outlet were about to be carried off in the stream of water. The eggs were left on the sides and bottom of the pan. They were then washed into a 100 ml. beaker by means of a wash bottle, and the contents poured slowly into a funnel sieve. Care should be exercised especially when large batches of eggs

have been collected as they may partially block the passage of water and rapid pouring may result in an overflow. The funnel sieve shown in Figure 2 may be held in position by a burette clamp on a ring stand or held in the hand while the eggs are being washed from the beaker. It consisted of a glass tube four inches in length, open at both ends, the outside diameter of which was three-fourths inch and large enough to allow the top half of a 10 ml. delivery pipette with the end covered with two thicknesses of a fine mesh organdy to fit snugly inside. After the eggs had been washed into the funnel, the delivery pipette was pushed upward through the open tube and the organdy removed.

The eggs were placed in an enameled pan 10 inches in diameter to hatch. The pan was filled with water to a depth of 1½ to 2 inches. A paraffined cardboard ring, 3½" o.d. and 2¼" i.d. was floated in the water. This was used to prevent the eggs from floating to the edge of the pan and adhering to the sides following evaporation of the water. The organdy covered with eggs was then placed on the

TABLE I

A COMPARISON OF RATE OF LARVAL DEVELOPMENT IN SHALLOW VERSUS DEEP WATER

NUMBER DAYS AFTER HATCHING	NUMBER PUPAE COLLECTED	
	Shallow Water	Deep Water
10	2	0
11	14	0
12	38	0
13	34	5
14	51	24
15	50	53
16	32	45
17	18	52
18	5	51
19	0	11
20	0	6
21	0	2
Total Pupae	250	250
Larval Mortality	7	22
Percentage Mortality	2 7	8 5

surface of the water inside the ring. The eggs floated off and the cloth sank to the bottom and was carefully removed with a pair of forceps. Two days after the eggs had been "set," hatching occurred. Several counts of the total number of larvae hatching from one day's supply revealed than from 3,000 to 10,000 eggs were deposited.

LARVAE.—Following hatching 250 larvae were counted into each of two oblong Pyrex dishes (No. 232) containing approximately 150 ml. of water. The number of larvae could be determined quickly and accurately by the use of an ordinary medicine dropper and a Veeder hand tally or counter. Groups of recently hatched larvae were sucked up in the medicine dropper and as they were slowly forced out into the water in the dish the number was recorded on the counter in the other hand. A white background was necessary in order to see the larvae easily. No further manipulation was required until pupation occurred.

The Pyrex dishes were selected because they were a standard product generally available, they had a flat bottom and were uniformly rectangular in shape which made possible efficient use of shelf space. They were 12 inches long, 8 inches wide and 2 inches high.

Depth of water was determined by a study of larval development in shallow and deep water. Two Pyrex dishes (No. 232) were used in the test, each containing approximately 250 larvae. Water depth in one was maintained at one-eighth inch which required 150 ml. of water, and in the other at one-half inch, requiring 600 ml. of water. The quantity of powdered food supplied each dish was the same. Repeated tests gave results similar to those shown in Table I.

These data show that the larvae in the shallow water developed more rapidly than those in deep water and with less mortality. This may be due to the fact that larvae in the shallow water swept the bottom with their mouth brushes and obtained the food that settled. They can do this with their respiratory plates remaining at the surface. The water was clear with no scum, and very few organisms such as bacteria or protozoa could be found indicating that they were unnecessary for proper larval development. The pupae from the deep water dish were smaller in size indicating inadequate food supply. Additional food added to the deep water dish to compensate for that which the larvae could not reach

TABLE II

A Comparison of Rates of Development of Larvae Using Dog Food and Yeast in Different Proportions

Number Days After Hatching	Number Pupae Collected Daily		
	Dog Food and Yeast, Equal Parts	Dog Food—1 part Yeast —2 parts	Dog Food—2 parts Yeast —1 part
9	9	1	1
10	59	21	15
11	93	91	81
12	67	88	82
13	14	28	53
14	1	8	11
15	0	1	1
Total Pupae	243	238	244
Mortality	7	5	9
Percentage Mortality	2 6%	2 05%	3 56%

because of settling, resulted in scum formation, a considerable amount of gelatinous, flaky, suspended material and murky water Microscopic examination of the water from such dishes revealed a very high population of bacteria, principally *Esherichia coli* and protozoa of the genera *Oikomonas*, *Hartmanella*, and *Colpoda* as determined by Professor W. J. Kostir and Dr. C. E. Venard. All these protozoa are air borne forms and primarily bacteria feeders. Once a dish became clouded or murky, death of most of the larvae was certain and if held for further development, a few larvae usually reached the pupal stage but the rate of development was greatly retarded. Results indicated that when this occurred it was best to dispose of the contents of the entire dish. An over-abundance of food, especially in the earlier instars increased the number of cloudy dishes.

A logical explanation for the greater mortality in the deep water dishes seemed to be that the excess food resulted in an abundance of bacteria, which appeared to be an ideal medium for protozoa because they increased greatly in numbers. The bacteria, being anaerobic, deoxygenated the water and along with the excess of food, a scum was produced on the surface that interfered with the dissolving of oxygen of the air into the water. The scum also clogged the respiratory plate

of the larvae causing them to struggle to free the plugged area, resulting in many of them being trapped in the flaky, gelatinous suspended material.

The larvae were fed *twice daily* with a mixture of equal parts by weight of finely ground[2] Purina dog food and powdered dried brewer's yeast. This mixture was tried in other proportions for effects on development and the results are shown in Table II. Peak pupation was reached more quickly when equal parts of dog food and yeast were used and mortality was greatest when dog food predominated and lowest when yeast predominated.

Studies were made on the amount of food required for each instar and the results are presented in Table III. Because all the larvae did not molt at the same time a safe range on quantity of food was given for the third and fourth instars which were the periods of greatest growth and food consumption With practice an approximation of these amounts could be administered by means of tapping a salt shaker containing the food mixture a given number of times Just as the food landed on the clear and ambered colored water, the small particles scattered rapidly over the entire surface. It was noted that this surface tension reaction did not take place in the dishes where the water was clouded

TABLE III

QUANTITIES OF FOOD FOR EACH INSTAR REQUIRED TWICE DAILY FOR 250 LARVAE

	Milligrams of Food per Dish of 250 Larvae, Fed Twice Daily			
	Instars			
	1	2	3	4
1 Slow Growth Low Mortality Water Clear	10	20	50	75
2. Normal Growth Low Mortality Water Clear	20	30	60 80	80 90
3 Normal Growth High Mortality Water murky plus scum and suspended flaky food material	30	40	90	100

Before the shallow water technique was proven to be superior to that of using deep water, a study was made of the possibility of changing the physical properties of the food so that it would float on the surface for several hours. After numerous trials this was accomplished by thoroughly mixing 160–175 ml. of water with a mixture of 50 grams of powdered dried brewer's yeast and 50 grams of finely ground dog food using an electric kitchen mixing machine. A teaspoonful of the resulting paste was then placed in the center of one-half of a sheet of waxed paper 6 x 12 inches. The other half of the paper was folded over the mixture and pressed between two panes of glass. This quantity of food mixture made a very thin layer six inches in diameter when treated in this way. When all of the food mixture had been pressed, the halves of the papers were separated and allowed to dry, after which they were crumpled to remove the flakes of food. These were broken up

[2]Laboratory model "Micropulverizer" with Herring bone Screen No. 035H B. S1.

so as to pass through 30 mesh screen, but in breaking them up some fine particles were produced and these were removed by sifting through an 80 mesh screen.

A check was then made on the relative merits of flaked versus powdered food in deep and shallow water. Two Pyrex trays were filled with 150 ml. of water and two with 600 ml. of water. Into each tray was then counted 255 larvae. The trays were fed once daily the same quantity of food. The results are given in Table IV. Repeated tests gave similar results.

TABLE IV

A Comparison of Rate of Development and Mortality in Shallow and Deep Water Using Flaked and Powdered Food

Number Days After Hatching	Number Pupae Collected			
	Powdered		Flaked	
	Shallow	Deep	Shallow	Deep
10				
11	42	7	30	12
12	125	56	89	48
13	65	82	84	75
14	1	18	42	59
15		13	8	36
16		4	1	15
17		1		3
Total pupae	233	181	254	248
Percentage Mortality	8.6%	29 0%	0 39%	2.7%

The results indicate that when powdered food was used the shallow water technique was superior to that of using deep water. Where flaked food was used very little difference in mortality resulted. The pupae from the deep water trays receiving powdered food were noticeably smaller. Since making flaked food is an additional chore its use is not recommended even though in this test it gave slightly lower mortality than powdered food in the shallow water trays.

Pupae.—The pupae were removed daily by means of a wide mouth medicine dropper and placed in four to six inches of fresh tap water in jars six inches in diameter. Jars this size will accommodate 600–800 pupae. Following removal of pupae the larvae from the last two or three dishes were combined into one dish to conserve space. The above described technique produced a daily average for the 7½ month period from December 1, 1944, to July 22, 1945, of 490 pupae with 94.8 per cent emergence and peak pupation in from 10 to 13 days after hatching.

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CHERMES ALNI, TWO CENTURIES AFTER KALM (HOMOPTERA: PSYLLIIDAE)[1]

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Apparently the definition of *Chermes alni* Linnaeus and the limitations imposed by the definition in the tenth edition of Systema Naturae, page 454, 1758, have either been ignored or not thoroughly investigated and the definition in Fauna Suecica, page 263, 1761, has been considered the original description; thus the entire concept of *Chermes alni* has been taken from this latter work. In his "Tenth Edition" Linnaeus states, "*Habitant in Betulae Alni ramulis Larvae, caudis plumosis tectae, in* America *septentrionali. Kalm.*" There is nothing in the International Rules of Zoological Nomenclature that invalidates this description. Since Peter Kalm is cited as collector of the insect under discussion any ecological data furnished by Kalm is certainly valuable and can not be discounted because of acquisition prior to 1758. An insect must be collected before it can be described and any data, whether pinned on the same pin as the specimen or not, should accompany the specimen. It is of further interest to note while Linnaeus' description of *alni* in the tenth edition has been ignored for purposes of original description, the North American record as taken from that work has been carried through the years and has recently resulted in *Psylla alni americana* Crawford being placed as a synonym of typical *alni* on the grounds that since *alni* was described from America *americana* must represent this form.[2] It should be noted in this connection that the American form described by Crawford as *americana* is known only from the far West. Had Kalm's notes been consulted it is not likely that this action would have been taken.

The English version of 1770, of Peter Kalm's travels in North America revised from the original Swedish and edited by Adolph B. Benson, on page 81, reads, "Chermes on the alder (*Chermes alni*)[3] were today found in great abundance on the branches of that tree, which for that reason looked almost white and at a distance appeared as if it were covered with mould." This account appears under Kalm's entry of October 3, 1748, on the journey to Wilmington, Delaware, from a farm near Philadelphia, Pennsylvania. These data with the original description furnish enough information to identify the insect as the only species covered with white flocculent material occurring in dense masses on the branches of alder in late fall in the vicinity of Philadelphia, Pa. On October 7, 1945, I was able to collect from alder immediately north and east of Philadelphia, and on October 12, 1945, I collected from alder immediately south and west of that city. Not one specimen of Psylliidae was taken from alder. Anyone contending that Kalm observed a species of Psylliidae has yet to report the occurrence under conditions described by Kalm of such an insect from Eastern North America to say nothing of the Philadelphia area. The topotypic insect found in such numbers as to make the alder branches appear covered with mould has been identified by the Bureau of Entomology and Plant Quarantine, Division of Insect Identification, as *Prociphilus tessellatus* (Fitch); therefore I am convinced that Kalm observed the insect known as *Prociphilus tessellatus* (Fitch) and that this species is a direct synonym of *Chermes alni* Linnaeus.

[1]An elucidation of the facts for authority to use the family name Psylliidae instead of Psyllidae or Chermidae. (See: Jr. N. Y. Ent. Soc. 52: 335, 1944.)

[2]Tuthill, L. D., Iowa State College Jr. Sci. 17: 460–461, 1943.

[3]The original reads, "*Chermes alni Linnei* Faun. Suec. 698." (See: En Resa til Norra America 2: 276, 1756.)

Since *alni* belongs in the Aphioidea and is the type species of the type genus *Psylla*, the family name goes with the zoological concept into the aphids. The next available type designation, which will maintain the zoological concept, is Kirkaldy's *Psyllia*, type *pyri* (L.) making the family name Psylliidae. Kirkaldy's type designation is definite and valid under the "Code" regardless of the reasons upon which he based his decisions. By admittance of these facts the old controversy of Chermidae vs. Psyllidae, which arose from Geoffroy's noncommittal treatment of a composite group that resulted in differences of opinion as to his intent, is legitimately and logically bypassed. There is no need to submit the question of Chermidae vs. Psyllidae to the International Commission for an opinion. Those who wish to preserve either name as a "*nomina conservanda*" must now submit a name based upon an interpretation of Geoffroy's intent as opposed to a name acceptable from both a zoological and nomenclatural viewpoint.

A NEW SPECIES OF TILLUS FROM ARIZONA (COLEOPTERA: CLERIDAE)

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Tillus patagoniae n. sp.

Male.—Somewhat resembling *Tillus collaris* Spin. in size, color and shape. Head, prothorax, scutellum, and last two visible ventral segments of abdomen reddish brown; elytra black; abdomen, antennae, and legs dark brown, tarsi lighter.

Head convex, surface finely densely punctured, light pubescence short; labrum entire; eyes emarginate, finely granulate; antennae with eleven segments, extending to basal fourth of elytra, segments five to ten inclusive serrate, slightly longer than wide.

Pronotum longer than wide, wider at apex than at base, widest in middle; sides sinuate; disc convex, with transverse depression near base and on anterior fourth; surface finely, densely punctured, light pubescence about same length as on head. Scutellum small.

Elytra much wider than widest part of pronotum, widest on apical third; sides subparallel near base, expanded back of middle, apices broadly rounded to suture; disc convex; surface with coarse punctures arranged in rows, separated by less than their own diameters, interspaces narrower than punctures, not visibly punctate, light pubescence short, dense.

Abdomen beneath shining, minutely punctured, pubescence sparse. All five tarsal segments visible from above.

Length 4 mm.; width 1.6 mm.

Female.—Last three visible ventral segments of abdomen reddish brown.

Variations.—Some specimens have the head dark, basal segments of antennae and abdomen lighter brown.

Described from specimens collected in the Patagonia Mountains, Arizona, on July 23, by D. J. & J. N. Knull. Male holotype, allotype and paratypes in writer's collection. Paratype in collection of The Ohio State University.

This species has shorter, wider elytra than *T. collaris* Spin. Elytral punctures are smaller and short, dense, light pubescence gives the elytra a gray appearance.

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[1]Contribution from Department of Zoology and Entomology.

A PHYLOGENETIC STUDY OF THE FERNS OF BURMA

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I. INTRODUCTION[2]

The purpose of this study is to arrange the ferns of Burma in the most natural system possible according to observed patterns of variation within the fern group.[3] This goal cannot be fully achieved at present because of the very inadequate paleontological record and the very incomplete knowledge of the morphological, anatomical, physiological, and chemical characters of both sporophyte and gametophyte generations of the genera and species involved. As Carl Christensen (1938) has pointed out, many important features observed in a single or few related species are not yet known to be characteristic of all species of the same genus; as a matter of fact hardly one character ascribed to a genus is to be found in all its species! Phylogenetic systems of classification of ferns to date should be recognized as provisional attempts to fit together and integrate the growing evidence available from all sources and to record tentative conclusions as to relationship.

The interpretation of data is a prime factor in the building of any phylogenetic system, for the seriation of individuals and groups depends upon the phylogenist's concept of progression. Phylogeny is in disrepute in some quarters (Bremekamp, 1942) because of the wide difference in interpretation of the same data. Since validity of the system rests upon the validity of the interpretation, it is essential that the principles of interpretation be clearly stated. It may well be that some of the elaborate taxonomic structures we have built are—like every other building—only structures. The quicker such fabrications are recognized and demolished, the quicker we will get to that final goal, a natural classification.

PHYLOGENETIC CONCEPTS AND THEIR MEASUREMENT

Somehow or other the present forms of life have arisen from fewer forms. Phylogenists attempt to systematize these organisms according to their true relationships. Inasmuch as some of the bases for such systems are of doubtful validity, a consideration of the concepts involved will be of value.

It is often taken for granted that recent ferns are more advanced than ancient ones, but this is not necessarily so. Eames (1936) states that some of the oldest

[1]Papers from the Department of Botany, The Ohio State University, Columbus 10, Ohio, No. 490.

[2]This paper represents part of a dissertation accepted by the Graduate School for the doctorate degree from the Ohio State University.

[3]My thanks are due to Dr. R. R. Stewart, Head of the Botany Department of Gordon College, Rawalpindi, India, for his continued encouragement, his aid in preliminary identification, and for his loan of Burma specimens after my Rangoon collection was in the hands of the Japanese; to the late Dr. Carl Christensen for his identification of my specimens of *Dryopteris* and *Polystichum;* to the late Dr. John H. Schaffner for his clearcut teaching on phylogenetic taxonomy; to the Chicago Museum of Natural History for the loan of the fern specimens collected by the Cutting Sikkim Expedition of the Field Museum; to the Rev. Harold Young for permission to study and name his fern collection made along the Stilwell Road on the Assam-Burma border; to the Arnold Arboretum for financial assistance in collecting in Burma; to Prof. C. A. Weatherby for making available the facilities of Gray Herbarium; to Dr. W. R. Maxon for his aid in identification and his kindness in making available the facilities of the U. S. National Herbarium; and to Dr. Lois Lampe and Dr. E. N. Transeau of Ohio State University for their reading of this manuscript and their helpful suggestions.

known forms of the Psilophytales are the most complex of that group suggesting that there must have been a long antecedent period of evolution. Campbell (1940) has pointed out that the Cycadofilicales may be considered as either the most advanced of the ferns or the most primitive of the gymnosperms. They are geologically ancient but definitely advanced in the possession of heterospory and seeds; they themselves were derived over a long preceding period from other and more primitive ferns. Had they survived to the present day, they would no doubt have been considered more advanced than our living ferns; the fact that very few of them survived the paleozoic period (Seward, 1931) in no way cancels out their advanced characteristics. Ancient ferns are not necessarily archetypic: the terms *ancient* and *recent* are not, therefore, to be used indiscriminately for *primitive* and advanced.

Bateson (1915) raises the question whether we are limited to the old view that evolutionary progress is from the simple to the complex, and whether, after all, it is conceivable that the progress was the other way about. Eames (1936) takes the position that some cases of simplicity are primitive and that others, due to reduction, are advanced. But can primitive simplicity be distinguished from simplicity due to reduction? Is *Monogramma dareicarpa* Hk. which Benedict (1919) claimed to be the simplest fern in existence, also the most primitive? Is the simplicity of the Hymenophyllaceae due to reduction as believed by Copeland (1938), or is it hereditarily simple? Such questions cannot be readily settled by appeal to the morphology of apparently simple organs; rather the complexity of the reaction system responsible for the organ must be studied. The complexity of the system is to be judged by the complexity of potentiality in the protoplast rather than by apparent complexity due to size or to a great multiplication or repetition of similar parts. (Schaffner, 1934.) Monogramma's one linear sorus located asymmetrically on a small leaf does not therefore indicate primitive simplicity.

Bower (1923), Copeland (1907, 1929a), and others have repeatedly judged those forms to be the most advanced whose structures seemed to have developed the most "biological advantage" by natural selection. As a matter of fact the degree of survival value of an organ is the second of the two touchstones used by Bower to determine which end of his phyletic series is to be considered primitive and which advanced. But as Cain (1944) has so clearly pointed out, although apparent biological advantage, gained through supposed adaptation of structure, is often superficially credible, yet it is never safe to reason from the structure to the function, as adaptation does not necessarily reside in the obvious but is rather the result of hereditary change. Care must therefore be exercised not to confuse apparent biological advantage with advance.

If phylogenetic advance cannot be measured directly by geologic age, nor by the degree of supposed biological advantage gained through selection, nor unerringly by the superficial complexity of organs, by what means can it be estimated?

First, different levels in the plant kingdom have been rather generally recognized by botanists, but these levels have been most clearly defined by Schaffner (1934, 1938, 1939). He carefully listed the fundamental potentialities of the reaction systems of the plants at ten different levels, and has shown that the majority of homosporous leptosporangiate ferns have 60 of these general potentialities, and the heterosporous ferns 69 to 70. These fundamental characters which determine the general level of ferns in the plant kingdom and, to a certain extent, within their own phylum, will be considered more fully in the section on the ground-plan of ferns.

To determine the relative position of any given fern within the phylum, one may catalog all the special characteristics which a species manifests throughout its life cycle in addition to the character-accumulation for the entire phylum to which it belongs, thus securing a list of the total potentialities or characteristics possessed

by that species. By this method Schaffner has shown *Ophioglossum vulgatum* L. to possess a total of 95 potentialities as against 105 for *Onoclea sensibilis* L. and 122 for *Marsilea quadrifolia* L. By such lists of the total character complex, the relative level or degree of advance of a species may be ascertained if the study of the various species is made on the same general basis. A simple listing of characters, without an attempt at evaluation, eliminates the possibility of arbitrariness in establishing relative values. The fact of accumulation of characters with resulting complexity should be a guiding principle in phylogenetic taxonomy.

One weakness in the use of the total character complex mentioned above would seem to be that all characters are considered to be of equal value in determining the degree of advance: a potentiality for reticulate venation is given equal weight with that for dichotomous venation; the potentiality for a well developed annulus counts no more than that for a vestigeal one. Therefore an additional way to determine the relative position of a fern within the phylum is to evaluate the morphological characters and functional activities as to their general or specialized nature. A thorough study of fern genera and species shows certain patterns of variation occurring repeatedly in different lines. In these phyletic series the more specialized forms are considered to be the more advanced. A detailed evaluation of the characters of leptosporangiate ferns will be found in a later section of this paper.

TYPES OF EVIDENCE ON WHICH A PHYLOGENETIC STUDY OF FERNS MAY BE BASED

Were it possible, a direct reconstruction of the historic development of ferns from fossil remains would give the most certain phylogenetic arrangement, for a complete record of the past, if properly interpreted, would establish the proper sequence of the taxonomic series. Unfortunately the fossil record is, and always will be, very fragmentary. Only a fraction of the kinds of ferns of the past have been preserved in fossil form, and of these only a fraction are recognizable specifically. Seward (1931) agrees that we cannot expect to discover a solution to the problem of evolution from the records of the rocks, though he does think that these fragmentary relics of the past enable us *to make tentative guesses* at the truth. Reference to such scattered and fragmentary fossil records as the chief method of determining which end of a phyletic series is primitive (Bower, 1923) is of doubtful validity. Whether the modifications in the various phyletic lines appeared in the historical order of the phyletic series, we have, in most cases, no direct way of checking; but as these variations have all appeared in the genetic complex, seriation from primitive to advanced is justifiable.

A second type of evidence frequently used in phyletic study is that from ontogeny. Bower (1923) holds that ontogeny reflects the probable phylogeny. But even though there may be a marked change in the structure and distribution of tissues or in the form of organs during the development of the individual, there seems to be little justification for claiming that the structure during the juvenile stage is more primitive than that of the adult stage just because the former precedes the latter. Both juvenile and adult forms are the expression of the same genetic complex. Such changes seem to be associated rather with changes in size of organs, patterns of growth, and physiological gradients. Phylogenetic variation may or may not run parallel with the changes occurring during ontogeny. It is an entirely different matter, and quite right, to consider the potentialities expressed throughout the life-cycle as a basis for the comparison of forms.

A third type of evidence valuable in phylogenetic taxonomy is the chemistry, whereby plants may be classified according to the substances made by them. By contrasting the protein precipitation reactions of a large number of ferns Mez (1925), Conradi (1926), Wilkoewitz (1929), and other workers have attempted

to establish the natural relationships of these plants. A diagram showing the conclusions of Mez is given by Gortner (1938). Chester (1937) has reviewed the results of this type of work and concludes that so many factors influence the strength of serological reactions that their value is chiefly qualitative rather than quantitative. This fact, together with the rather widely varying results obtained by the workers in the Konigsberg and Berlin schools, definitely limits the serological approach to the interpretation of plant relationship. It is probable, however, that this method might contribute information if techniques were better standardized, and if more species were tested. At present, so far as ferns are concerned, the results may be considered as suggestive only.

McNair (1932, 1934, 1935, 1945) has attempted to use a different type of chemical evidence on which to base relationships. He maintains that the higher the relative molecular weights of the plant alkaloids, the more unsaturated the fats, the higher the specific gravities of the volatile oils and the lower their refractive indices, the more advanced the plant or plant group. Although he has not dealt with the ferns, his method would be applicable to them. One serious weakness of his theory is that the chemical values which he uses vary rather markedly in the same plant when grown in different environmental conditions.. For instance, the iodine number of linseed oil varies from 175–210. With such a range of variation any indicated relationship would, of necessity, be very indefinite. Results for plants grown in the same controlled environment might be significant. Another weakness is that the range of iodine values is greater within the single order Ranales, 31–129, than in most of the other angiospermic families put together. Since this is true, what value can there be in the comparative averages for the large groups with which he works?

Other chemical evidence such as that supplied by color reactions of lignin (Crocker, 1921) may ultimately prove of value in phylogenetic taxonomy.

A fourth kind of evidence is that derived from genetics and cytology (Cain, 1944). Gregory (1941), McKelvey and Sax (1933), Foster (1933), Whitaker (1933), Cleland (1936), and others have applied such evidence to good effect in clearing up the systematics of certain angiospermic groups. For example, it has been shown that polyploidy has been very important in developing large, complex, and widespread angiospermic genera. The genetic analysis of ferns, however, has only just begun (Anderson-Kötto, 1938), and thus far very little use of results has been made. That such use will bring worthwhile results is shown by the study made by Conley (1944) in which she shows that *Nephrolepis exaltata* and some of its varieties fall into three groups with chromosome numbers 76±, 57±, and 28±.

A fifth type of evidence, and most important in this study, is that derived from the physiology, morphology, and life-cycle of living ferns. Since the beginning of the century it has become more widely accepted that since ferns lack flowers—structures on which the taxonomy and phylogeny of the angiosperms is almost entirely based—any natural taxonomic arrangement of ferns must be based on the very broad foundation of the morphological and physiological characteristics of all organs of the plant during its development. This at once makes the study of fern relationship much more difficult not only because the basis of comparison is wider but also because evidence derived from different organs may not be readily harmonized. We are lead to the conclusion that all organs do not progress phyletically at equal rates; one organ or part may have advanced decidedly while another remained stationary (Bower, 1923, Schaffner, 1934). Despite this inequality of advance of different organs of the same fern, the ideal of phylogenetic taxonomy is to base the system on the sum of all available evidence.

Bower, in his invaluable work, The Ferns (1923, 1926, 1929) established twelve criteria of comparison by the use of which he tried to work out the true relationship of ferns. They are:

1) The external morphology of the shoot.
2) The initial constitution of the plant body as indicated by meristematic segmentation.
3) The architecture and venation of the leaf.
4) The vascular system of the shoot.
5) The dermal appendages.
6) The position and structure of the sorus.
7) The indusial appendages.
8) The characteristics of the sporangium and spores.
9) The spore numbers.
10) The morphology of the prothallus.
11) The position and structure of the sexual organs.
12) The embryology of the sporophyte with special reference to the suspensor.

In the present state of our knowledge some of these criteria such as Nos 2, 10, 11, 12, and to some extent No. 9, seem to be of importance in distinguishing the eusporangiate from leptosporangiate ferns Inasmuch as the leptosporangiates differ from the eusporangiates in so many fundamental ways that they seem unlikely to have been derived from the fully evolved eusporangiate ferns, this study will confine itself to those criteria deemed valuable in the study of the leptosporangiate ferns.

Smith (1938) in his summary of developments within the fern group makes no reference to Bower's Nos. 2 and 5. Eames (1926) believes that No. 12 has no real value for comparison. But if Bower includes some criteria which are not particularly useful in this study, he also overlooks some. To his criteria should certainly be added:

13) The development and differentiation of sporophylls
14) The time of sex-determination in the life-cycle

It will be noted that these fourteen criteria are, in the main, morphological in nature. Our very limited knowledge of the physiology, and of growth and differentiation, forces us to express our conclusions at present largely in morphological terms, but ultimately when it becomes possible to speak in terms of patterns of growth, the present rather confused picture of such things as leaf type, architecture, and venation may be cleared up (Foster, 1936).

From this survey of evidence available for use in a phylogenetic study of the ferns, it would seem that very heavy reliance must still be placed on the morphological life history, though the physiology, chemistry, and genetics of ferns may prove to be of increasing value in years to come

II. A Review of the Schemes of Classification Proposed Since the Beginning of the Century

The usual practice in the past in the segregation of families has been to put all ferns with a more or less complete vertical annulus into the family Polypodiaceae, thus including in one family ⅚ of all living ferns. The other ⅙ have been, without much difficulty, separated by marked segregative characteristics of annulus and vegetative form into about 15 other very natural and often isolated families by such men as Robert Brown, Martius, Kaulfuss, John Smith, Presl, and Bower. These are composed of such similar and easily recognized forms that there is more or less general agreement as to their treatment. The real phylogenetic problem, therefore, rests not with them but with that great residual group of about 7,000 species which have been lumped together on the basis of one character, the more or less vertical annulus. It is with them that we shall deal in this review. For an excellent survey of the earlier treatment of these ferns, reference may be made to John Smith's *Historia Filicum* (1875).

Diels (1902) divided the "Polypodiaceae" into 9 tribes, 6 of which were subdivided into 2 subtribes each, and 1 into 4 subtribes. Christensen (1906) arranges the Polypodiaceae according to Diels' outline without change. Bower (1928) makes 11 tribes which are based directly on the tribes and subtribes of Diels, with the one exception that he breaks up Diels' No. IX, Acrosticheae, inserting most of the acrostichoid species under other tribes as acrostichoid derivatives. Copeland (1929) gives numbers rather than names to his divisions of the family which he enlarges to include such genera as *Plagiogyria, Cyathea, Dicksonia, Cibotium,* and *Matonia* in order to preserve the Polypodiaceae as one phylogenetic unit (a procedure which is not likely to stand). He disagrees with Diels and Bower as to the relationship of many separate genera, but there is a more or less close correspondence of his groups with theirs, as shown in Chart I.

CHART I

A Comparison of the Sections of Copeland and Diels

Note: The first digit of Copeland's numbers indicates the phyletic line, and successive figures branches of these lines.

Copeland	Diels	
121–123	I.	Woodsieae
124	II.	Aspidieae
1252	V.	Asplenieae Blechninae
1253	V.	Asplenieae Aspleniinae
241 and 32	IV.	Davallieae
242	VI.	Pterideae
30	III.	Oleandreae
421 and 422	VIII.	Polypodieae, Section 1
423-426	VIII.	Polypodieae, Section 2
51–54	VII.	Vittarieae

Christensen, in his *Third Supplement* to the *Index Filicum* (1934) again, follows Diels' order but makes changes here and there which bring his system closer to Copeland's. Christensen clearly states that this is only a partial revision as he was preparing a thorough one to appear four years later in the *Manual of Pteridology* (1938). In that, his final and most complete revision, he divides the old comprehensive, Polypodiaceae into 15 subfamilies which, he says, might better be considered as families. Christensen does not follow Diels in placing the annual water fern, *Ceratopteris*, in a family by itself; rather he makes it a tribe in his subfamily VI, the Gymnogrammeoideae. Nor does he follow Bower in placing *Dipteris* in a separate family, instead, making it his subfamily XIII, the Dipteroideae. Also he separates the Lindsayoid ferns from the Davallioid, putting them into his subfamily II, the Lindsayoideae. In other respects his groups correspond very closely with the tribes and subtribes of Diels and Bower, as may be seen by reference to Chart II.

CHART II

COMPARISON OF THE TREATMENT OF THE POLYPODIACEAE BY CHRISTENSEN, BOWER, AND DIELS

NOTE: The roman numeral before each group refers to its original position in the list to which it belongs. The arabic numerals refer to the subsections of the larger groups.

CHRISTENSEN	BOWER	DIELS
I. Dennstaedtioideae	I. Dennstaedtiinae	IV. Davallieae In part
II. Lindsayoideae	II. Davallioid ferns Section 3	IV. Davallieae In part
III. Davallioideae	II. Davallioid ferns Sections 1 and 2	IV. Davallieae In part
IV. Oleandroideae	II. Davallioid ferns Of uncertain place	III Oleandreae
V. Pteroideae	III Pteroid ferns	VI Pterideae 4. Pteridinae
VI. Gymnogrammeoideae 1. Cryptogrammeae 2. Ceratopterideae 2. Gymnogrammeae 4. Adianteae 5. Cheilantheae	IV. Gymnogrammeoid ferns 1. Primitive genera 1. Primitive genera 2. Central group 3. Adantoid ferns 4. Cheilanthoid ferns	VI. Pterideae 2. Cheilanthinae (PARKERIACEAE) 1. Gymnogramminae 3. Adiantinae 2. Cheilanthinae
VII. Vittarioideae	XI. Vittarioid ferns	VII. Vittarieae
VIII. Onocleoideae	VII. Onocleoid ferns	I. Woodsieae 2. Onocleinae
IX. Blechnoideae	VIII. Blechnoid ferns Sections 1, 2 and 3	V. Asplenieae 2. Blechninae
X. Aspleniciideae	VIII. Blechnoid ferns Section 4 VI. Asplenioid ferns	V. Asplenieae 1. Aspleninae 1. Aspleninae
XI. Woodsioideae	V. Dryopteroid ferns 1. Woodsieae	I. Woodsieae 1. Woodsiinae
XII. Dryopteroideae	V. Dryopteroid ferns 2. Aspidieae	II. Aspidieae 1. Aspidiinae
XIII. Dipteroideae	(DIPTERIDACEAE)	II. Aspidieae 2. Dipteridinae
XIV. Polypodioideae	IX. Dipteroid derivatives	VIII. Polypodieae IX. Acrosticheae 2. Platyceriinae
XV. Elaphoglossoideae	X. Metaxyoid ferns Section 2	IX. Acrosticheae 1. Acrostichinae

The most adventurous treatment of the old group, "Polypodiaceae" is that by R. C. Ching, ***On the Natural Classification of the Family "Polypodiaceae"*** (1940), in which he divides the 170 or so genera with a more or less vertical annulus into 33 families, 21 of which closely parallel Christensen's subfamilies and tribes, the other 12 being segregates of one or several genera from groups where they did not seem to be closely related. It may be questioned whether anything is gained by treating

such groups as families rather than subfamilies and tribes, but in any case Ching seems to have done the logical thing in breaking up into natural families the old "Polypodiaceae," if that group be truly polyphyletic as Bower and Christensen believe. In most cases he has defined natural groups and established order by increasing the number of subdivisions of the Filicales; in this way the number of units per group decreases, and they may be more easily surveyed. See Chart III.

CHART III

COMPARISON OF THE TREATMENT OF "POLYPODIACEAE" BY CHING AND CHRISTENSEN

NOTE: The dots indicate side branches from the main series.

Ching	*Christensen*
LINDSAYOID-DAVALLIOID SERIES	
1. Culcitaceae Ching	Dicksoniaceae—Dicksonioideae (part) (or in I. Dennstaedtioideae)
2. Dennstaedtiaceae Ching	I. Dennstaedtioideae—Dennstaedtieae
Dennstaedtieae	Chaetopterides
Saccolomeae	Lepidopterides
3. Lindsayaceae Ching	II. Lindsayoideae
Lindsayaeae	
Taenitideae	
Stenolomeae	
4. Dictyoxiphiaceae Ching	II. Lindsayoideae (1 genus)
5. Davalliaceae Gaud.	III Davallioideae
Davallioideae	
Nephrolepioideae	
6. Oleandraceae Ching	IV. Oleandroideae
PTEROID-GYMNOGRAMMEOID SERIES	
7. Hypolepidaceae Ching	I. Dennstaedtioideae—Hypolepideae
8. Pteridaceae Ching	V. Pteridoideae
Lonchitideae	Chaetopterides
Pterideae	Lepidopterides
9. Sinopteridaceae Koidzumi	VI. Gymnogrammeoideae (part)
Onychieae	Cryptogrammeae (a)
Allosoreae	Cryptogrammeae (b)
Cheilantheae	Cheilantheae
10. Gymnogrammaceae Ching	VI. Gymnogrammeoideae (part)
Gymnogrammeae	Gymnogrammeae—Chaetopterides
Gymnopterideae	Gymnogrammeae—Lepidopterides
11. Adiantaceae Presl	VI. Gymnogrammeoideae (part)
	Adianteae
. . . .	
12 Ceratopteridaceae C. Chr.	VI Gymnogrammeoideae (part)
	Ceratopterideae
. . .	
13. Antrophyaceae Ching	VII. Vittarioideae
	Part of B
14. Vittariaceae Presl., emend.	VII. Vittarioideae
Monogrammeae	Part A
Vittareae	Part of B
15 Loxogrammaceae Ching	XIV. Polypodioideae (1 genus)
THELYPTEROID-ASPLENIOID SERIES	
16. Aspleniaceae Presl.	X. Asplenioideae
Asplenieae	Asplenieae
Athyrieae	Athyrieae
17. Thelypteridaceae Ching	XII. Dryopteridoideae (part)
Thelypterideae	Thelypterideae (1st part)
Goniopterideae	Thelypterideae (2nd part)
Dictyoclineae	Dryopterideae (Sect. of Tectaria)
18. Sphaerostephanaceae Ching	XII. Dryopteridoideae (part)
	Thelypterideae (1 genus)
19. Monachosoraceae Ching	XII. Dryopteroideae (part)
	Thelypterideae (2 genera)
. . . .	
20. Blechnaceae Ching	IX. Blechnoideae
Blechneae	
Woodwardieae	
Braineae	

CHART III—(*Continued*)

Ching		*Christensen*	
CYATHEOID-ASPIDIOID SERIES			
21.	Onocleaceae Ching	VIII.	Onocleoideae
22.	Woodsiaceae Ching	XI.	Woodsioideae
23.	Hypoderriaceae Ching		Between XI and XII
24.	Perenemaceae Presl., emend		Between XI and XII
25.	Aspidiaceae Presl., emend.	XII.	Dryopteroideae
	Dryopterideae		Dryopterideae (Nos. 1-18)
	Aspideae		Dryopterideae (Nos. 19-37)
26.	Didymochlaenaceae Ching	XII.	Dryopteroideae
			Dryopterideae (1 species)
27.	Acrostichaceae Presl., emend.	V.	Pteridoideae (derivatives)
DIPTEROID-POLYPODIOID SERIES			
28.	Cheiropleuriaceae Nakai	XIV.	Polypodioideae
			Chaetopterides, 1 genus
29	Dipteridaceae Bower	XIII.	Dipteridoideae
30.	Platyceriaceae Ching	XIV	Polypodioideae
			Chaetopterides, 1 genus
31	Polypodiaceae Presl. (sensu propria)	XIV.	Polypodioideae—Lepidopterides
	Pleopeltoideae		Pleopeltideae
	Lepisoreae		Nos. 4 10
	Phymatodeae		Nos. 11-36
	Polypodioideae		Polypodieae
	Polypodieae		Nos. 37 40
	Campyloneureae		No. 41
32.	Grammitaceae Presl , emend	XIV.	Polypodioideae—Lepidopterides
	Grammitieae		Polypodieae Nos 42-48
	Cochlidieae		Polypodieae Nos. 49-51
33.	Elaphoglossaceae Ching	XV.	Elaphoglossoideae

Unfortunately from the point of view of phylogeny, Ching is, on the whole, very dogmatic in his segregations, in very few cases giving adequate discussion or sufficient explanation of the bases for his divisions, and nowhere stating any principles by which he interprets his data However, Ching worked with Carl Christensen for several years and followed his ideas very closely, so that, in a sense, Ching carried the work of Christensen to a logical conclusion. Christensen here and there states the principles on which he builds his system, but he nowhere draws them together in a unified statement. As a matter of fact no fern taxonomist has adequately presented the principles upon which he has based his phylogenetic disposition of species. True, here and there statements are made which help us to understand the points of view, but these tend to be scattered and incomplete. The morphologists have been less hesitant in trying to formulate principles of progression; certain it is that a statement of principles is essential if these are to be accurately understood and assessed.

III. THE GROUND-PLAN OF FERNS

If we are to arrange the ferns in series from the primitive to the more advanced, it is essential to have a starting place. Different workers vary widely in their conception of the theoretical primitive type. Bower (1935) pictures it as follows: "Such an ***archetype sporophyte*** would have consisted of a simple upright shoot of radial symmetry, probably rootless, dichotomising if it branched at all, and with the distinction between leaf and axis either absent or ill-defined. The leaf, where recognizable as such, would have been long stalked, with distal dichotomy, tending in advanced forms towards the sympodial development of a dichopodium. All the limbs of the dichotomy would be narrow and distinct from one another. The

whole plant would be relatively robust as regards cellular construction, generally photosynthetic, and traversed by conducting strands with a solid xylem-core. The surface would be glabrous, or invested with simple enations. The solitary sporangia would be relatively large, and distal in position, with thick walls, and a simple method of dehiscence; and each would contain numerous homosporous spores." Bower carefully states that he is not implying that the Psilophytales represent the direct ancestry of the Filicales, but if the above description of the supposed primitive fern type implies anything, it is just that. Campbell (1940) says that there is some evidence that the Filicineae may have been derived from some of the Devonian Psilophyta but that it is problematical. He pictures the primitive sporophyte as consisting of a single leaf and a "protocorm" or foot, with the root presumably being of later development. Eames (1936) comments on the proposed primitive type by saying, "The Psilophytales are indeed 'ancient and simple;' that they are also 'archaic and ancestral' is not surely known."

Though the relationship of the ferns and the Psilophyta is problematical and unproven, Bower and his followers do base their ideas of progression and development directly on that assumption, even to the cladode nature of the megaphyll or fern leaf. The present writer believes that so long as the actual origin of the ferns is so uncertain, it is unwise to start with an assumption which, if untrue, would invalidate the whole phylogenetic structure built upon it.

Must we than conclude with Seward (1931) that the theoretical primitive type eludes our grasp; that though our faith postulates its existence, yet that type has failed to materialize? Fortunately there is an alternative far safer than to base our type on a very problematical ancestry, and far more positive than to make no effort at all. A generalized ground-plan can be drawn for the ferns by placing together those fundamental potentialities of the phylum to which they belong (Schaffner, 1934) but which appear for the first time in the plant kingdom as we know it in the ferns. Such a generalized type for the homosporous ferns would show the following characteristics: it would have a 2-phased sporophyte with a parasitic embryonic stage and a later completely independent stage. The sporophyte would have either an unbranched or a branched stem with long-continued, indeterminate apical growth. The stem tip would display either negative or transverse geotropism; the well developed vascular system would be composed of xylem and phloem. On the stem in a spiral pattern would be typical leaves with a vascular supply; these would be decidedly dorsiventral, usually with phototropic reactions when young. In most lines they would have a circinate vernation. Sporangia producing spores of one kind would be borne on the leaves. Spore formation would not be followed by the immediate death of the sporophyte except where the potentiality for continued growth were inhibited by the introduction of the annual habit as in *Ceratopteris.*

This is the ground-plan for all homosporous ferns; to get to the heterosporous ferns there would have to be added to this character complex the fundamental potentiality which causes a shift in the time of sex-determination from the ontogeny of the gametophyte back to the sporophyte, resulting in heterospory and highly dimorphic unisexual gametophytes which are also much reduced, short-lived, and dependent on the parent sporophyte for their food supply.

The above description is made up of the fundamental characteristics of all the ferns. It is, therefore, a generalized picture which is as true for primitive as for advanced forms. Since it is impossible, as Seward has intimated, to postulate with any certainty the theoretical primitive type for the ferns, this ground-plan which must have been true for the primitive type also, is the next best approach. We have than a starting place for our study, not theoretical and postulated, but actual. The evolution of the ferns has consisted in the variation of expression of this ground-plan at every point and in any number of different ways.

IV. The Phyletic Patterns of Variation of the Leptosporangiate Ferns

A taxonomist trained to work with specific and generic plant types and precise descriptions of plant organs and structures is often at a loss to know how to harmonize his concepts with those of the newer morphology of the last two decades (Watson, 1943) whose trend has been away from fixed categories and static concepts of structural and specific entities towards a more dynamic and fluid condition. The terms *leaf* and *stem* have become for some no more than convenient descriptive words without biological meaning (Arbor, 1930). The species is "a momentary realization of a line of evolution (Faegri, 1935). Concepts which describe form are being replaced by concepts dealing with the regulation of growth (Schuepp, 1933). However, as Watson (1943) points out, although the nature of the descriptive terms or units employed be changed, yet units of some kind are indispensable for all description. By building on the most fully substantiated morphological concepts of the past until they are actually replaced by something nearer the truth, and at the same time making use of new facts available from all sources, the taxonomist can approach with confidence a study of the phyletic patterns of variation among the ferns.

1. Posture. As often happens in phylogeny, experts may disagree in their interpretations: whereas Bower (1923) holds the erect stem to be the more primitive type, Eames (1936) says that the rhizome type appears primitive for the group. Copeland (1938) believes that at least for the Hymenophyllaceae the creeping rhizome is primitive and the ascending or erect stem derived.

The pose of the adult stem is not determined by its orientation in the embryo but rather by the direction of growth of the young stem. Stems may be upright from the first by continued growth of an erect embryo as in *Angiopteris* if the stem be negatively geotropic; but if, as in the case of *Helminthostachys*, it be transversely geotropic, then it quickly grows to a prone position. In the majority of the leptosporangiates where the embryonic stem is lateral and prone, the growth of the young stem is negatively geotropic and by continued growth becomes erect as in *Cyathea* and *Brainea*, or suberect as in *Polystichum*. If, however, the young stem displays transverse geotropism, it will continue to grow in a prone position. The negatively geotropic growth of erect stems with radial symmetry would seem by analogy with other vascular plants to be the more fundamental; horizontal growth with its various and frequent change of symmetry, the more specialized and derived. Ferns having both erect stems and runners or rhizomes as in *Matteuccia struthiopteris* Tod., in *Nephrolepis cordifolia*, and in some species of the Cyatheaceae are considered here to be more advanced in this respect than related forms with only a single stem type.

2. Other specialized forms of stems. Those specialized forms of stems such as the tuberous stems of *Nephrolepis cordifolia* and *Todea barbata*, the inflated and hollow (sometimes ant-inhabited) stem of *Myrmecophila*, the climbing stems of *Stenochlaena* and *Lomagramma*, the runners with distinct nodes and internodes of *Marsilea*, and the rhizophores of *Oleandra neriiformis* are considered as derived and advanced, not because of any degree of supposed biological advantage associated with the structure, but because some very real new potentialities have been added to a primitive ground plan complex. They should not be thought of as "adaptations"—past, present, or future!

3. Rate of growth. The rate of growth varies from very slow as in most erect stems and some prostrate ones, to very rapid as in ferns like *Marsilea* and *Lomagramma*. Judging by comparison with the eusporangiate ferns and the Cycadophyta the slow growth associated with upright stems would seem to be the relatively more primitive condition. It is also associated with a more complex phyllotaxy which in a later section is considered to be a primitive characteristic.

Secondary growth due to a vascular cambium must also represent an added protoplasmic potentiality.

4. BRANCHING OF STEM. The upright fern stem is normally unbranched though apical twinning sometimes takes place, involving presumably the equal division of the apical meristem. In no upright fern stems known to the writer is there repeated and regular dichotomous branching, and Wardlaw (1943b) points out that what Bower considered in many ferns to be delayed branches of unequal dichotomy probably have a different origin. Dobbie (1929, 1930) tells of a forest of forked tree ferns in New Zealand, but he attributes such branching to adventitious buds rather than to dichotomy. Wardlaw (1943 a and b) gives very interesting evidence to show that the branches of the erect stems of *Matteuccia struthiopteris* which form horizontal rhizomes can be traced to "detached meristems" to be found always in proximity to regions of meristele conjunction His investigations with other ferns such as *Dryopteris aristata* and *Onoclea sensibilis* suggest that buds on fern stems near leaf bases are not adventitious; their position is regular and fixed in relation to the meristele conjunctions, that is axillary in origin though often moved out of the axil by growth distortion.

Prostrate stems may be unbranched, may branch by dichotomy as in *Pteridium aquilinum* and *Onoclea sensibilis*, by axillary buds as in the Hymenophyllaceae, *Marsilea*, and *Leptochilus axillaris* (Cav.) Kaulf., or by buds not distinctly in the axils of leaves as in *Onoclea sensibilis* which Wardlaw has shown to be of probable axillary origin. It would seem that branching due to buds associated with leaf bases represents a potentiality added to the unbranched or dichotomously branched condition. If branching by both dichotomy and axillary buds is present as in *Onoclea*, two heritable factors for branching must be present and consequently the hereditary reaction system of the plant may be considered more complex.

5. STELE. Bower places great emphasis on the comparative value of the stele type, concluding that "the vascular tissues provide the most constant character of the plant body." Van Tieghem's stelar theory (1886) has furnished material for much phylogenetic discussion. It has been held by Gwynne Vaughan (1901), Bower (1923), Eames (1936), Smith (1938), and Campball (1940) that the protostele is primitive and that the siphonostele and dictyostele are successively more advanced. One hesitates to take a position which differs from that of such an impressive group of authorities, but their position needs to be carefully reconsidered in the light of recent research. The evidence for their belief is based on the fact that some of the Gleicheniaceae and Schizaeaceae, and the Hymenophyllaceae, which are for other reasons regarded as ancient and primitive, possess a protostele in their adult stems. Among ferns with a polypodioid type of sporangium protostely may be found in *Cheiropleuria* and the tribe Monogrammeae of the family Vittariaceae.

Let us examine this evidence to see if it is sufficient to warrant the conclusion that protostely is the primitive condition. First, not all of the species of the Gleicheniaceae are protostelic, one section of the family having solenosteles. The same may be said, and more emphatically, for the Schizaeaceae, because of the four genera of that tribe only one, *Schizaea*, is protostelic: *Lygodium* is solenostelic, and *Anemia* and *Mohria* are dictyostelic. If protostely is the primitive condition, certainly it is not very well fixed, for other types of steles seem to be more common than protostely in these presumably primitive families. And what about the Hymenophyllaceae in which protostely is rather more universal? Copeland (1938) believes that reduction is the key to an understanding of the family. If this is true, protostely in the family may be the result of reduction and therefore not a primitive characteristic.

Certainly evidence from these supposedly primitive families is not very convincing, particularly when added to it is the fact that protostely never occurs in

the adult stems of other supposedly primitive fern families and genera. The Ophioglossaceae have solenosteles or dictyosteles, while the Marattiaceae and Angiopteridaceae have what Bower (1926) called "undoubtedly the most complex vascular system of all living Pteridophyta," a polycylic dictyostele. The Osmundaceae have dictyosteles, and the Matonaceae have "one of the most complicated solenostelic structures among ferns," a polycyclic solenostele with three concentric rings of vascular tissue. Certainly the evidence from living ferns supposedly primitive is very unconvincing. If one bases his judgment on the living evidence, the decision would have to be otherwise.

The second type of evidence which has lead to the conclusion that the protostele is more primitive than the solenostele, and the latter more primitive than the dictyostele, comes from the ontogeny of the fern plant. A young sporeling usually has a protostele, but in all except the few genera named above where the adult stem retains the protostelic structure, as the stem grows and increases in diameter upward, the stele develops into a siphonostele or solenostele, and sometimes into a dictostele. By taking the events of ontogeny as a pattern for phylogeny the case for the primitive nature of the protostele is established to the satisfaction of some.

Just what is involved in the change from protostele to dictyostele? In the course of individual development the simple protostele may become medulated, a condition which leads to solenostely, and this, in turn, in shoots where the foliar gaps overlap, to dictyostely. Wardlaw (1944a) has pointed out that the condition of the fully differentiated tissues in the basal portion of the young stem where protostely exists is primarily referable to the size, activity, and nutritional status of the apical meristem at the time of inception of that stage; and similarly for the fully developed tissues in the higher region where a solenostele is formed. He also shows (1944b) that the leaf gaps in the shoot stele do not form if leaf primordia are destroyed at a sufficiently early stage, and that the solenostele which would have become a dictyostele due to overlapping of leaf gaps, remains a solenostele. Therefore, the condition of the differentiated tissues in the upper, normally dictyostelic level of the stem is referable not only to the size, activity, and nutritional status of the apex at the time of the inception of that stage, but also to the modifying influence of developing leaves. He thus demonstrates very clearly that there is no phylogenetic difference between a solenostele and a dictyostele, and little or none between a protostele and solenostele.

The increasing size of the apical meristem, then, plays a definite part in the shift from protostely to solenostely, but not from solenostely to dictyostely which is controlled by leaf development. It should be pointed out, however, that there are a few cases of "perforated" dictyostele, as in leafless tubers of *Nephrolepis cordifolia* (Sahni, 1916), where increasing size of the organ appears to be of importance in determining the internal morphology.

What then can be concluded about the occurrence of stele types and their phylogenetic significance? Dictyostely is normally associated with erect and suberect stems, and with decumbent stems which are relatively thick and whose leaves are close and many ranked so that the leaf gaps overlap. Siphonosteles are normally associated with prostrate stems of smaller diameter having leaves few ranked and (or) so far apart that the gaps do not overlap. Protostely in fern stems is usually associated with prostrate stems of small diameter. If the large erect stem with many-ranked leaves is primitive, and the decumbent stem with few-ranked leaves is derivative, then in that sense the dictyostele may be considered more primitive than the solenostele and protostele. But since the stele type is so closely associated with the stem size, stem posture, and leaf arrangement, it would seem that these characters have been far more important phylogenetically than the stele type. In this discussion, therefore, little value will be attached to it.

6. EPIDERMAL OUTGROWTHS OF THE SHOOT. Christensen (1911) says that

the best and most constant specific character is to be found in the dermal appendages, hairs and scales. These appendages may vary within a species, in abundance but not in kind. They may be remarkably constant for a whole genus as in *Pyrrhosia*, or extremely variable as in *Asplenium*.

Some genera such as *Microlepia* may possess hairs only, while others such as *Cyathea* may have some species with hairs and some with scales; *Histiopteris* may have both hairs and scales on the same shoot. Families such as the Osmundaceae includes genera which are all characterized by hairs only, while others such as the Oleandraceae have scales only on their stems but may have hairs on their leaves. Such families as the Schizaeaceae, Gleicheniaceae, Cyatheaceae, Gymnopteridaceae, and Thelypteridaceae have both hairs and scales occurring in their genera or sections. It is clear then that though the kind of dermal appendage may be constant within a species, it is not necessarily so in larger groups. Since both hairs and scales are present in such supposedly primitive families as the Gleicheniaceae and Schizaeaceae, it is apparent that hairs and scales are not very fundamentally different, and their presence, though of specific value, may not be of great phylogenetic significance.

The simple hair is the product of a simpler growth process than a branched or stellate one, or than a scale. Hairs vary from one- to many-celled, and from unbranched to branched. Scales vary in shape, size, color, point of attachment, thickness of walls, and margin; it seems impossible to trace any one pattern of variation for all scales. A few generalizations, however, may be made: a scale with a basal point of attachment may be more easily derived from a hair than one with a broad base or one peltately attached. Clathrate scales having thick cell walls and clear lumen seem more specialized than those with smaller undifferentiated cells without clear lumen. Scales with entire margins may be simpler than those with dentate or ciliate margins. A glabrous shoot may be thought of as more primitive than one having a potentiality for the development of dermal outgrowths; care must be taken, however, not to mistake an adult shoot from which the outgrowths have dropped or been rubbed off for a truly glabrous one.

Before considering patterns of variation of the fern leaf it will be well to examine briefly the recent thought concerning the nature of the leaf. It may be summed up thus (Bower, 1935): the megaphyll, or leaf of the ferns proper, is of cladode nature, i. e., it is a modified branch system having its origin in the dichotemous branching of a stem not yet fully differentiated as axis and appendage. Since the leaf is supposed to be only a stem, primitive leaves would be highly branched, the various branches being green and not webbed together. Although Bower has based his phyletic series on this hypothesis, he was not satisfied that it represented ultimate truth as may be seen by a statement of his (1938) in the introduction of Verdoorn's Manual of Pteridology: "Certainly the last word . . . on the origin of leaves . . . has not yet been spoken." We agree with this opinion.

Not only is the actual origin of fern leaves still quite uncertain, but letosporangiate fern leaves differ in some very fundamental ways from all known branch systems in their circinate vernation during the growing period of the leaf, their direct spiral arrangement on the stem, the sporadic or regular presence of buds in their axils, and the reticulate venation of the leaves of many species. The distinctness of the leaf and stem, often from the quadrant stage of the embryo, is a strong argument that the leaf is not simply one limb of a dichotomously branched stem. Since the origin of the fern leaf is not really known, and since it differs in these fundamental ways from known branch systems, in this study the older morphological concept of the leaf as an organ distinct in nature from the stem and root will be maintained. What is primitive in the patterns of variation will not be decided on the assumption that the psilophytan branch system is the prototype of the leaf, but upon other criteria.

7. PHYLLOTAXY. As Schaffner has so well shown in his paper on the Spiral Systems in Vascular Plants (1938a) there is a general progression from the complicated multispiral leaf arrangement to the alternate 2-ranked condition, and in a very few cases to the 1-ranked condition. His generalizations hold for the ferns, those with relatively large erect or suberect stems and dictyosteles having many-ranked leaves as is also the case in some decumbent stems with dictyosteles, for example, ***Pteridium aquilinum***. In many decumbent stems, particularly in those with a siphonostele or protostele the leaves are two-ranked (or in some cases possibly one-ranked). Rarely leaves are whorled as in ***Salvinia*** where three leaves occur at each node, and as in some species of the Cyatheaceae where whorls of 3, 4, 5, and 6 leaves are known. In whorled types 3 or more leaves develop almost simultaneously. As has been pointed out above, the phyllotaxy is always correlated with the stele type, and both are correlated with the stem type or posture.

8. ARTICULATION OF THE PETIOLE TO THE STEM AND ABSCISSION. John Smith (1875) held the articulation of the petiole to the stem to be a character of such prime importance that he used it together with a phyllotaxis character to found his primary section Eremobrya. The present writer cannot follow Smith in making articulation a framework character for the segregation of ferns into large primary groups, but it is a specific or generic character. Very frequently articulation, together with abscission, is associated with an epiphytic habit as in *Oleandra*, *Davallia*, and some of the Polypodiaceae ***sensu strictu***. That it is in no sense limited to epiphytes can be seen from its occurrence in *Cyathea*, *Angiopteris*, ***Elpahoglossum***, and a few species of ***Asplenium***. Articulation is a character which would have to be added to the ground-plan complex, and its presence is therefore to be considered an advanced character.

9. ARTICULATION OF PINNAE OR PINNULES TO RACHIS OR RACHILLA. John Smith (1875) did not include in his section Eremobrya those ferns lacking articulation at the base of the petiole even if their pinnae were articulated to the rachis. Such articulation, very frequently resulting in abscission on drying, is present in ***Nephrolepis***, ***Drynaria***, ***Lomagramma***, ***Stenochlaena***, ***Dicymochlaena***, ***Angiopteris***, ***Woodsia*** Sect., ***Physematium***, and in some species of ***Adiantum*** and ***Lygodium***. Such articulation may or may not be associated with an epiphytic habit, although the first two genera mentioned above have many epiphytic species. The succeeding genera and species mentioned are typical terrestrial ferns, so that it would be inaccurate to conclude with Copeland (1907) that articulation arises as an adaptation to the epiphytic habit, and to habitats where ferns must sometimes endure a more or less prolonged drought. Were this true, we might expect articulation and abscission to be present in all epiphytes and in most terrestrial ferns of monsoon regions, where the rainfall is seasonal, but this is not the case.

Such articulation may characterize whole genera as ***Drynaria*** or only certain species in a genus as in ***Lygodium***. Its occurrence in the ferns as a whole does not seem to form a pattern or to parallel any one or more phyletic lines, but rather appears here and there as a marked character. Its presence indicates the addition of a new factor to the ground-plan complex; ferns having articulation are to be considered that much more complex in their development than those which lack it.

10. LEAF TRACES. The number and arrangement of the meristeles, or vascular bundles, in the petiole base at the point of union with the stem is a diagnostic character of importance which is easily ascertained in fresh material. This information should be recorded in the description of all species; at present generalizations are difficult because this is one of those characters which Christensen might have had in mind when he said that many important characters known to exist in some species of a genus are not yet known to occur in all. However, Waters (1903) has used this character on which to base a key to the ferns, and Ching (1940) in his key to the 33 families which he segregated from the old

family "Polypodiaceae," divides them into two groups, the first having one leaf trace, and the second, two or more traces. Unfortunately there are always exceptions which make unsatisfactory the use of this character with as large groups as families.

Wardlaw (1944b) shows that in young petiole bases the procambial strands are uninterrupted and crescent-shaped, made up of small-celled tissue which during growth fails to keep pace with the enlargement of the pith within; hence the vascular crescent becomes disrupted into five to seven or more separate strands or traces. If, however, the further growth of the primordium is inhibited or prevented at an early stage, the normal enlargement of the pith does not take place and the crescentic mass of primordial vascular tissue remains coherent or disrupted only to a limited extent. It is possible that what Wardlaw has found to be true for ***Dryopteris*** spp. may also hold for other ferns in which the leaf trace or traces are arranged in the form of a horseshoe, trough, or V. It would seem then that the pattern of variation of leaf-traces in ferns with dictyosteles is from the continuous shapes just mentioned to the interrupted C or V, the individual meristeles of which may be either elongated or rounded. In ferns with decumbent or climbing stems, distant leaves, and protostele or solenostele, the petiole bases usually have one trace either round or V-shaped,—rarely split into two traces. There is no such irregular arrangement of traces at the petiole base as that shown for ***Pteridium aquilinum*** by Waters (1903).

11. DEGREE OF DISSECTION OF THE BLADE. It should be recalled that in this study the fern leaf is treated as an organ ***sui generis*** and not as of cladode origin. Should the megaphyll sometime be really proved to be a modified branch system, this section and certain others concerning the leaf would have to be completely revised. Bower (1923) and all those who like him establish their ideas of the fern leaf on the very problematical psilophytan ancestry of the ferns hold that the large highly divided leaf is more primitive than a smaller simple leaf; that the simple or less divided forms have arisen from the more divided by the webbing of branches. This is the logical conclusion if the leaf originated from a much branched stem system; if the leaf is an organ distinct in nature from a stem, then the question of whether the primitive leaf is simple or compound is an open one and not predetermined by a theory. Let us examine the leaves of ferns from this point of view.

First of all, what are the facts regarding the occurrence of simple and compound leaves in the ferns? In almost every large family as well as in genera represented by a large number of species are ferns having leaves with all stages of division of the blade from simple and entire to highly divided. For instance, the genus *Cyathea* which is usually thought of as characterized by gigantic decompound leaves, really has species with all degrees of division from the undivided leaf as in *Cyathea sinuata* Hk., to simply pinnate as in *C. brunonis* Wall., to bipinnatifid in *C. alternans* (Wall.) Pr., to bipinnate-tripinnatifid in *C. latebrosa* (Wall.) Copel., to tripinnate in *C. tripinnata* Copel.

The same is true of the family Hymenophyllaceae in which leaf blades range from simple and entire to 4- or 5-pinnate. It is more of a surprise to those acquainted primarily with the ferns of the northern United States to find that the same range of blade division may be found in the genus ***Adiantum***. Several species of the simple-leaved maiden hair fern exist, one of which, ***Adiantum parishii*** Hk., grows in Burma. There are many species with 1-pinnate leaves such as ***A. philippense*** L. and ***A. caudatum*** L.; with 2-pinnate leaves as in ***A. capillus-veneris*** L., and with 3-pinnate leaves as in ***A. cuneatum*** Langsd. & Fisch. Similar series occur in ***Asplenium*** and ***Diplazium***.

In some families and genera the highly divided leaves are missing or rare, and simple or 1-pinnate forms predominate as in ***Phymatodes***. Sometimes a whole genus is characterized by simple entire leaves as in ***Pyrrhosia***, but even here one is

not surprised to find species with palmatifid or pinnatifid blades Evidently in such cases the series has never developed beyond the second stage In other families and genera the simple end of the series may be missing as in ***Microlepia*** in which all forms from the 1-pinnate to highly compound are known. The potentiality for the development of this pattern of variation of the leaf blade is certainly present in most of the large families. This is so general that if one of the forms is not known from one section of the world, it probably can be found in some other or in fossil form.

Can it be established which end of the series is the more primitive? Foster (1936) in working with angiospermic leaves has shown that the blade develops from two elongated lateral meristems along the sides of the costa. If this develops uniformly without break, the blade is simple; but if the lateral meristem soon becomes localized rather than continuous, then the blade developed will be divided or compound. In other words, to get more highly compound leaves a more extreme development of localized and isolated blade meristems is necessary Such a distribution of meristems seems to represent a more complex system of primordia than a simple continuous one along a continuous costa. To some extent the degree of division may increase somewhat with increasing size of the leaf unless the veins are very close together as in ***Thamnopteris***, ***Microsorium***, ***Phymatodes***, and ***Platycerium***.

Fertile juvenile leaves produced on the not yet fully mature stems of many species which normally have compound leaves such as ***Drynaria quercifolia*** and ***Arthromeric wallichiana*** are often simple or have very few lobes or pinnae Ching says that far too many ferns have been described for China because juvenile forms with simple leaves have often been described as new species. The fact that juvenile leaves of many compound-leaved species precede the compound during ontogeny is not evidence that the simple leaf is more primitive than the compound, yet this occurrence does give an illustration of what takes place when a stem which has produced simple leaves begins to produce more divided ones. With increase in age and possibly in the size of the leaf primordia, there is a localization of the meristematic tissue referred to above which results in compounding No case is known to the writer where leaves produced by increasingly mature plants are less divided than the leaves produced earlier unless the complicating factor of reproduction begins to operate If the highly divided blade be the primitive form as so widely accepted, then we will have to conclude that as a fern plant reaches maturity, its leaf-form reverts more and more to the primitive condition That this could be almost universally so seems hard to credit.

If any portion of a blade be more highly divided than another, it is the basal part as illustrated by ***Lindsaya orbiculata*** (Lam.) Mett., in which several basal pinnae are again pinnate, and the upper pinnae are entire or only slightly incised This is true for most ferns which have deltoid leaf blades. The lower pinnae are formed before the apical ones, originate from larger lateral pinnal meristems, and are less quickly determinate in their growth than the apical pinnae. In fact these lower pinnae tend to repeat the architecture of the apical portion of the main blade and to approach it in size. The more highly divided lower pinnae of many species is an indication of the tendency to a greater degree of division of the blade.

One of the common variations in leaves is the cresting or forking of the pinnae of such ferns as ***Nephrolepis***, ***Osmunda***, ***Polystichum***, and ***Pteris***. Bower (1923) says that such cresting is essentially reversion. Tryon (1938) considers the fluctuating types of cresting as reversionary, but the heritable kinds as advance. Conley (1944) has shown that in some of the crested varieties of ***Nephrolepis exaltata*** that a correlation exists between anatomical differences and chromosome number and that none of the forms studied seemed to represent the parent diploid complex. Such evidence seems to indicate that cresting in ***Nephrolepis*** is associated

with polyploidy, hybridization, or reduction of chromosome number below the normal diploid complement. If there is no evidence that cresting with the consequent greater division of the blade is an advanced character, at least there seems to be no ground for hasty conclusion that it is reversionary and that the divided condition of the blade is primitive.

All of the above lines of evidence seem to point to the correctness of the view that variation in the fern leaf progresses from simple to divided and compound.

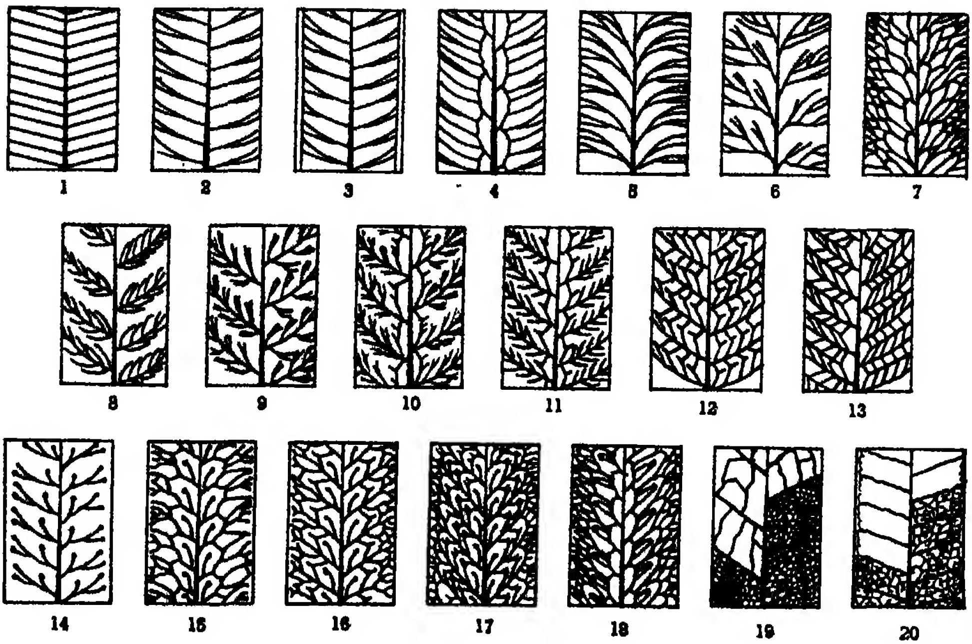
12. VENATION. If Wardlaw's hypothesis (1944a) to account for the initial differentiation of vascular tissues in ferns should hold for the veins of the leaf, then different venation patterns would result from amazingly different patterns of growth in the leaf blade; for Wardlaw suggests that the initial differentiation of vascular tissue takes place immediately below or behind a meristematic center and "in the path of substances diffusing from it, one or more of these substances being casually involved in the process." If this is true, then the venation would be the blueprint of the pattern of growth of the leaf blade, particularly complicated in leaves with reticulate venation. Since no other more probable working hypothesis has been proposed to date, we shall examine the evidence from this point of view.

When the apical meristem of the leaf primordium divides by equal dichotomy, the main veins are dichotomously branched as in *Dipteris conjugata;* when the apical meristem divides unequally and one sidedly, catadromic helicoid main veins result as in *Matonia pectinata* and *Adiantum pedatum*, or anadromix helicoid main veins as in the fossil *Dictyophyllum exile*. If the apical meristem divides by unequal dichotomy, the subordinate shanks being alternately right and left, a zigzag or geniculate midrib or rachis develops which appears to be a continuation of the petiole. An extreme example is *Rumohra diffracta* (Bak.) Cl. Bower (1923) points out that when such a central axis of the blade is well developed, the primordia of the lower pinnae appear at a point below the apex of the leaf as lateral outgrowths upon it. Such branching of the axis is, in reality, monopodial. No clear line can be drawn between the monopodial and extreme cases of unequal dichotomy where alternate shanks develop into the subordinate branches. The architecture of the leaf may be determined, then, by the type of branching of the apical meristem, whether by equal or unequal dichotomy or by monopodial division.

The secondary veins in the pinnae or ultimate segments of the blade are exceedingly varied. Where the apical meristem of the leaflet primordium divides dichotomously from the beginning, a dichotomous pattern of veins is produced as in many species of *Lindsaya*, *Adiantum* and *Asplenium*.

Where the apical meristem of the leaflet maintains its dominance, a midrib is produced and lateral veins grow outward from along its sides in a pinnate pattern presumably developing immediately back of meristematic centers located on the margin of the leaflet primordium. When these centers are close together, simple, unbranched, costaeform veins result, Fig. 1. Where some of the meristematic centers divide equally, once-branched veins are formed as in some species of *Oleandra*. Fig. 2. These lateral veins may be free and end at or near the margin, or they may be united at their tips by a connecting marginal vein as in *Thamnopteris*, Fig. 3. Where the meristematic centers are further separated on the primordial blade margin, they tend to divide dichotomously more than once to form a fascicle as in *Osmunda javanica*, Fig. 4. Where the shanks of the dichotomy are unequal, a fascicle is formed intermediate between a sympodium and a monopodium as in *Asplenium adiantum-nigrum*, Fig. 5.

In some species the lowest veins of adjoining fascicles grow toward each other and unite, forming an arching vein more or less parallel with the costa, from which arch grow out either simple or once-branched veins as in *Brainea insignis*, Fig. 6. Or the branches of adjoining fascicles may unite to form uniform areoles without



TYPES OF VENATION

EXPLANATION OF FIGURES 1-20

NOTE: The names of the types of venation are those proposed by Georg Mettenius (1856).

Fig. 1. Costaeform venation.
Fig. 2. Taeniopteroid venation as in *Oleandra*.
Fig. 3. Venation as in *Thamnopteris*.
Fig. 4. Neuropteroid venation as in *Osmunda javanica*.
Fig. 5. Sphenopteroid venation as in *Asplenium adiantum-nigrum*.
Fig. 6. Venation as in *Brainea insignis*, approaching the Doodyoid type.
Fig. 7. Sagenioid venation of *Schizoloma ensifolia*.
Fig. 8. Pecopteroid venation as in *Matteuccia orientalis*.
Fig. 9. Pecopteroid venation as in *Cibotium barometz*.
Fig. 10. Pleocnemioid venation as in *Pteris biaurita*.
Fig. 11. Venation as in *Cyclosorus*.
Fig. 12. Goniopteroid venation as in *Abacopteris*.
Fig. 13. Goniopteroid venation as in *Goniopteris prolifera*.
Fig. 14. Eupteroid venation as in *Polypodium vulgare*.
Fig. 15. Marginarioid venation as in *Polypodium amoenum*.
Fig. 16. Goniophlebioid venation as in *Polypodium subauriculatum*.
Fig. 17. Cyrtophlebioid venation as in *Cyrtomium folcatum*.
Fig. 18. Phlebodioid venation as in *Polypoidum aureum*.
Fig. 19. Drynarioid venation as in *Drynaria quercifolia*.
Fig. 20. Anaxetioid venation as in *Lepisorus*, *Microsorium*, and *Phymatodes*.

free included veinlets as in *Schizaloma ensifolia*, Fig. 7. In many natural genera there are sections with free veins and others in which the venation is similar except that some or all the veins unite to form regular areoles without free included veinlets, as may be illustrated by the following genera or sections:

Veins free	*Veins anastomosing*
Lygodium	Lydodidictyon
Aneimia	Aneimidictyon
Davallia	Diellia
Pteridium	Lonchitis
Pteris	Histiopteris
Asplenium	Asplenidictyon
Diplazium	Allantodia

It is evident from such a list as this that free and reticulate venation are not two fundamentally different things, but rather that reticulate venation may develop from the open type wherever a diverging meristematic center on the margin of the blade primordium meets and merges with an adjacent center.

In simple leaves, leaflets, or ultimate segments of a compound blade the fascicles of veins which arise from the midrib may be pinnately branched, not forked as in some of the foregoing examples. These branches may themselves be simple and unforked as in *Matteuccia orientalis*, Fig. 8, or forked as in *Cibotium barometz*, Fig. 9. The lowest veins of adjacent fascicles may unite to form a costal arch with free excurrent veinlets as in *Pteris biaurita*, Fig. 10, and *Cyclosorus*, Fig. 11. Sometimes all of the lateral veins may unite angularly with excurrent veinlets which may or may not extend to the next higher pair of united veinlets as in *Abacopteris*, Fig. 12, and in *Goniopteris prolifera*, Fig. 13.

A fourth general pattern of venation is found in the Polypodiaceae. In the ultimate lobes or segments there may be veinlet fascicles in which the lowest branch on the side towards the apex of the segment is short and quickly determinate, not reaching the margin. The other branches of the same fascicle may be free and nearly reach the margin as in *Polypodium vulgare*, Fig 14; or they may unite forming one row of areoles with free excurrent veinlets running to the margin, as in *Polypodium amoenum*, Fig. 15; or they may unite to form two or more rows of areoles with one excurrent veinlet in each areole as in *Polypodium subauriculatum*, Fig. 16; or with several excurrent veinlets in each areole as in *Cyrtomium falcatum*, Fig. 17. A variation of this pattern in which the two included veinlets meet and fuse, gives the venation of *Polypodium aureum*, Fig. 18. A second modification of the type of venation in Fig. 17 may have given the close reticulum without free included veinlets found in *Drynaria quercifolia*, Fig. 19. Still a third modification of the same venation, in which the free included veinlets are irregularly oriented, appears in *Lepisorus*, *Microsorium* and *Phymatodes*, Fig. 20.

To summarize, it may be said that several patterns of variation of the veins of fern leaves exist, and that in general in each series open venation represents a simpler growth pattern of the margin meristematic centers in the leaf primordia than does reticulate venation.

13. Fertile areas of the leaf. One of the first things that attracts attention in the study of fertile leaves of such genera as *Osmunda*, *Aneimia*, or *Polystichum* is that the area of the leaf which is fertile varies markedly in different ferns. In

EXPLANATION OF PLATE II

Fig. 21. Unilaterally dimorphic leaf of *Onoclea sensibilis*.
Fig. 22. Unilaterally dimorphic leaf of *Pteris cretica*.
Fig. 23. Hemidimorphic leaf of *Osmunda cinnamomea* forma *frondosa*.
Fig. 24. Series of leaves of *Onoclea sensibilis* from vegetative to reproductive.

some cases the transition between fertile and sterile regions is gradual, in others abrupt. By a study of certain species in which the leaf is fertile only in part, we may reach conclusions very different from that reached by Bower (1923) when he states, "The lower parts of the leaf are more exposed, and this may explain the frequent absence of sporangia at the base. *Osmunda regalis* is an example of this."

Thus, *Osmunda regalis* may have only a few of its apical pinnae fertile, but in any large collection specimens may be found which show many more fertile upper pinnae, perhaps all on the upper half of the leaf. *Osmunda japonica* of Burma has a sporophyll of which all the pinnae are fertile from the apex to the base, though in other respects it is identical with *O. regalis*. Evidently we have here a physiological condition which in *O. regalis* does not become established until after the "foliar determination" (Foster, 1936) of the basal and first formed part of the leaf has become fixed in a prospective vegetative course of development. In *O. japonica* the condition changes from the vegetative to the reproductive state earlier in the ontogeny of the leaf, with the result that the entire blade is fertile. Similarly in *Polystichum acrostichoides* specimens may be found which vary from those having only a few apical pinnae fertile to those in which all but the lowest few are fertile. Here again there must be a variation in the time at which the change takes place from the vegetative to the reproductive condition. Where the change is early enough in the ontogeny, the whole blade may be fertile.

Osmunda cinnamomea which normally has the sporophyll completely fertile from base to tip, sometimes has leaves in which the apical half only is fertile. In literature this is called *Osmunda cinnamomea* forma *frondosa*, Fig. 23. Porter (1930) reported leaves with only one or two fertile pinnae at the top. Had the shift to the reproductive condition come any later in such leaves, there would have been no fertile pinnae at all. It may be inferred from such examples that physiological states are involved, that where a shift occurs from the vegetative to the reproductive state late in the ontogeny of the leaf, only the tip is fertile; but that with a progressively earlier change to the reproductive condition, more and more of the leaf becomes fertile until a completely fertile leaf is produced.

In species such as *Osmunda vachellii* Hk. only the basal pinnae are fertile; evidently here the change from vegetative to reproductive state, comes in early during the development of the leaf, but quickly shifts back again to the vegetative with the result that the later-formed parts of the blade are purely vegetative. In the very similar *O. javanica* Bl. the temporary shift from the vegetative to the reproductive condition comes slightly later, with the result that a few medial pinnae are fertile. The same timing exists in *O. claytoniana*, our common interrupted fern, in which from one to six medial pinnae may be fertile, depending on how long the reproductive condition remains. It is possible to conceive of a growth substance, a sporogen, as being involved in such shifts of the physiological condition.

A study of certain cases of unilateral dimorphism, in which one side of a leaf is fertile and the other sterile, may provide further evidence, for example, a specimen of *Onoclea sensibilis* from Ohio, Fig. 21, of *Pteris cretica* from the Himalayas, Fig. 22, and of *Dryopteris thelypteris* mentioned by Blake (1933). Evidently the physiological condition on one side of the leaf was continuously reproductive while, at the same time, that operating on the other side was continuously vegetative. In each of these species there are two leaf traces entering the petiole base. It would seem that the hypothetical hormone regulating spore production might be supplied through one trace to one side but not through the second trace to the other side: no cases of such unilateral fertility have been found by the writer in leaves having other than two leaf traces. Whatever it is that regulates spore production, it must be able to work in this unilateral manner at least when two leaf traces are present, as well as in the vertical zonal manner already referred to.

Although no general survey has ever been made as to the occurrence of different fertility patterns, the least frequent pattern is probably that in which only a few pinnae near the middle of the leaf are fertile; the next more frequent, that in which only the basal part of the blade is fertile. Probably the most common pattern is that in which the leaf is fertile to varying degrees from the tip downward, often resulting in a completely fertile leaf.

Knowing no more than we do about the real cause of the change from the vegetative to the reproductive state, it is difficult to establish one fertility pattern as more advanced than another. Until further facts become known, we shall work on the supposition that there is a progressively earlier shift from the vegetative to the reproductive condition of the leaf during the ontogeny of the plant, and that there is a progressively increasing duration of the reproductive state once it has been initiated.

14. VEGETATIVE AND REPRODUCTIVE LEAF FORMS. Dimorphism of the vegetative and reproductive leaves, or parts of leaves, is rather commonly supposed to be more or less restricted among the eusporangiate forms to the Bortychiales, and to *Osmunda* and a few other genera such as *Matteuccia* and *Onoclea* among the leptosporangiate ferns. The idea of such a restricted occurrence of dimorphism arises, perhaps, from a study of the rather meager American fern flora in which there are comparatively few cases of dimorphism. Though general in the Ophioglossales, dimorphism is by no means limited to that order. In both the Marattiales and the Filicales examples of dimorphism are to be found in most of the families and in over 55 genera.

Dimorphism is neither limited to one phyletic line nor restricted to ferns of any one habit or habitat. Extreme forms of dimorphism are illustrated by such aquatic ferns as *Ceratopteris thalictroides*, by such swamp ferns as *Osmunda cinnamomena*, by such mesophytic ferns as *Bolbitis*, *Egenolfia*, and *Plagiogyria*, by such epiphytes as *Platycerium* and *Drymoglossum*, by such xerophytes as *Pteris cretica*, and by such climbing ferns as *Stenochlaena*. Evidently dimorphism has not arisen in response to any given set of environmental factors, and cannot be considered as "adaptive."

There are varying degrees of difference between the vegetative and fertile parts, from subdimorphism to extreme dimorphism. Where such differentiation appears in different parts of the same leaf, the term ***hemidimorphism*** is used instead of ***dimorphism***. The modification involved in the differentiation of the sporophylls are many and varied, as may be seen from the following tabulation of differences:

1. Length of the petiole: the petioles of the sporophylls may be longer than those of the vegetative leaves as in *Hemionitis arifolia*, or shorter as in *Matteuccia struthiopteris*.

2. Expansion of the blade: The blade of the sporophyll may expand during ontogeny only slightly or none at all, as in *Egenolfia*. A similar contraction of the sporophyll is evident in the Cycadophyta.

3. Shape of the blade: the blades of the sporophylls may be of a different shape than those of vegetative leaves. For example, sporophyll blades of *Drymoglossum pilosiloides* and *Phymatodes rhyncophylla* (Hk.) Ching are linear and the vegetative blades round or oval.

4. Leaf margin: the margin of the sporophyll as of *Pteris cretica* may be entire, that of the vegetative leaf toothed.

5. Degree of dissection: the sporophyll may be much more deeply lobed or divided than the vegetative leaf as in *Doryopteris ludens*, or much less deeply lobed or divided as in *Riphidopteris peltata* (Sw.) Schott.

6. Synthesis of chlorophyll: the sporophylls may lack chlorophyll as in *Osmunda japonica*. A similar condition is found in *Equisetum arvense*, the most advanced of the horsetails.

7. Duration of the leaf: sporophylls may be very ephemeral as in *Osmunda cinnamomea*.

8. Season of production: in some ferns such as *Osmunda japonica*, the sporophylls appear before the vegetative leaves; in others such as *Ceratopteris*, *Onoclea*, and *Matteuccia* they appear much later.

Explanations of many different kinds have been offered to account for dimorphism. "Physiological advantage" has been invoked by Copeland (1907, 1929a); "use and disuse," by Clute (1908). When it is recognized, however, that dimorphic and monomorphic species grow side by side in the same habitat and survive equally well, such explanations become mere hypothetical modes of escape.

Some evidence from intermediate forms of normally dimorphic species such as *Osmunda cinnamomena* has been offered by Clute (1905) to show that injury to the rhizome may affect the degree of dimorphism of the leaves produced, but Breckenridge (1917) showed that such injury was not involved in the production of intermediate forms of the leaves of *Onoclea sensibilis*. Road tar was suggested as the cause of the production of the *frondosa* form of *Osmunda cinnamomena* (House, 1933), but leaves of this type have been found by the writer where no such material was present. Atkinson (1894) claimed that a modification of the nutritional balance of the plant through the removal of all vegetative leaves resulted in the production of leaves intermediate between the sterile and reproductive, but similar observations made by Breckenridge (1917) failed to confirm the earlier results. Atkinson (1911) also claimed that fire injury could be the cause of intermediate forms. Price (1912) and Weatherby (1937) considered that light intensity and moisture conditions affect the degree of blade expansion of sporophylls. However, none of the suggested environmental factors can explain the existence of dimorphism itself.

Unfortunately there is very little definite information about the growth and differentiation of the tissues of fern leaves; for this reason it is impossible at present to explain just what happens when the expansion of the fern leaf is inhibited at the time of spore production. The fact that dimorphism is normally associated with areas which are reproductive shows that both the change in the anatomy of the leaf and the production of sporangia are consequences of the same factor or complex of factors. It would seem that in some ferns the hormones that induce spore production modify the effects of growth substances probably associated with the lateral meristem which develops the blade. That this inhibiting action may be slight, medium, more marked, or extreme is beautifully illustrated by forms of *Onoclea sensibilis*, Fig. 24, in which a closely graded series of leaves may be found from the fully expanded and slightly lobed, wholly vegetative leaf, through forms increasingly smaller, more deeply lobed, and sometimes sparsely sporogenous, to the extremely reduced fertile blade with bead-like, fertile, inrolled lobes.

The production of sporophylls and vegetative leaves at different seasons may well be a photoperiodic phenomenon. Small plants of *Ceratopteris thalictroides* (L.) Brongn., placed by the author in the greenhouse at Ohio State University on July 7, 1945, under 14-hour summer day-length, began producing sporophylls by August 8, whereas it was not until September 1 that plants kept in light of 8-10-hour duration produced the first sporophyll (and that only after the plants had received, by accident, full length summer daylight over a weekend). On six plants kept under continuous light only one sporophyll was produced by September 25th; the vegetative growth was luxuriant. It would seem possible that the photoperiod regulates the formation of the sporogen. Further experiments, more critically controlled, should be conducted with *Ceratopteris*.

The phylogenetic significance of dimorphism of vegetative leaf and sporophyll is evident from a survey of the vascular plants as a whole. Sporophylls, including stamens and carpels, being organs homologous with vegetative leaves, (Bower, 1923) are considered more advanced the more they differ from vegetative leaves. There is a progression from the generalized processes of a double-duty, monomorphic

leaf to the more specialized processes of dimorphic leaves. Monomorphic leaves are held, therefore, to be more primitive than hemidimorphic or dimorphic leaves. A genus in which dimorphism is characteristic is to be considered more advanced than a genus with largely monomorphic leaves, other characters being similar. There seems to be no factual basis for distinguishing primitive and advanced types of dimorphism as Eames (1936) does except as a consequence of the cladode hypothesis of leaf origin which is here considered as untenable.

15. DIMORPHISM OF VEGETATIVE LEAVES. Some ferns have in addition to sporophylls two kinds of vegetative leaves. For instance, ***Matteuccia struthiopteris*** has bipinnatifid vegetative leaves on its upright stems, and in addition has large scale-leaves on its prostrate stems. The high-climbing ferns ***Lomagramma*** and ***Teratophyllum*** (Holttum, 1937a, 1937b) have acrophylls which are the leaves formed at high levels in the forest, and bathyphylls which are formed at the ground level. These upper and lower vegetative leaves differ in shape and degree of division of their blades. The epiphytic fern, ***Drynaria***, has deeply-pinnatifid and long-petioled ordinary vegetative leaves, and sessile, less deeply-pinnatifid sterile leaves in the axils of which humus often collects. The primordial patterns of species having several kinds of leaves are considered to be more complex, and therefore more advanced, than those of a species having only one kind of leaf.

16. POSITION OF THE SORI. Basing their speculation on the cladode hypothesis of the leaf and the psilophytan origin of the ferns, Bower (1923) and those following him (Eames, 1936, Campbell, 1940, etc.) concluded that the position of the sori at the margins must be more primitive than that on the abaxial surface of the leaf. These authors arrived at this conclusion by reasoning that since the sporangia of the postulated primitive types were apical on the branches, and since leaves are considered to be simply branches of a stem which had become united by webbing, then the marginal position of sori on a leaf blade would correspond with the apical position on unwebbed branches. These are quite logical deductions from highly speculative premises. Advance, from this point of view, would consist in any shift of the sori from their marginal position to the abaxial surface of the blade, a movement called by Bower (1923) "the phylogenetic slide." So fundamental does Bower think the soral position to be that he uses it as the primary character on which to base his three phyletic lines of leptosporangiate ferns: the Marginales, the Superficiales, and the non-soral Osmunda-Gymnogrammeoid line.

On the other hand, if the theory be accepted that in the phylogenetic development of the sporophyte of the Metathallophyta there has been a progressive movement of spore production from the central axis to the periphery of the sporophyte, then the logical conclusion would be that marginal sori are more advanced than those on the abaxial surface because they are at the determinate limit of movement away from the axis of the sporophyte.

Copeland (1907) has proposed that the advanced position of the sorus is that reached by the adaptation of the reproductive structures to their habitats: "The principles underlying the adaptations of the reproductive structures of ferns are very simple. . . . . The mature spores must dry thoroughly enough to be easily and well scattered, and yet the drying of the spore must not involve too great a dessication of the frond." Since the marginal or apical position of the sori permits spore distribution without undue drying of the blade, the marginal position would thus be one of the most advanced. This is pure and quite unnecessary teleological theorizing.

Deductions such as those drawn from the preceding three theories may be logical but not necessarily fit the facts. Let us therefore examine the soral positions and see whether the question of what is primitive and what is advanced may be settled aside from an appeal to these philosophical theories. Sori occur at the

following places on fern leaves: first, lateral on the veins on the abaxial surface of the leaf blade, or very rarely on the adaxial side as in *Polystichum anomalum* J. Sm.; second, lateral on the veins and on the epidermal tissue between the veins, a condition usually called acrostichoid; third, apical on the veins. In some cases the veins end at the leaf margin so that apical sori and marginal sori become the same; in other cases, Figs. 14–18, 20, some veins end far short of the margin; sori terminating such veins are superficial on the abaxial surface.

From dry herbarium specimens of acrostichoid species with much contracted sporophylls, it is difficult in most cases to ascertain whether the sporangia are really scattered over the surface or are borne on linear or punctiform receptacles which are very close together as a result of lack of expansion of the blade. Fresh material and occasional intermediate forms of sporophylls, which are partially expanded, provide enough evidence to permit a decision.

A distinction between sori which are apical on veins and those which are lateral on them is far more fundamental than a distinction between sori which are marginal and those which are "superficial" on the abaxial surface, inasmuch as sori apical on veins may be either marginal or surficial. According to Bower's scheme, *Nephrolepis* belongs to the Marginales group, yet in most of the species the sori are not marginal but definitely intramarginal or medial. Bower would explain this situation by saying that a phylogenetic slide of the sorus from the margin to the abaxial surface has taken place in *Nephrolepis* so that the sori are no longer truly marginal. Certainly such a system is taxonomically very unusable because many species with "superficial" sori are placed in the Marginales and many species with marginal sori are placed in the Superficiales.

Whether the sori of *Nephrolepis* are medial, intramarginal, or marginal, in all cases they are apical on veins. The same may be said of the rest of the Davalliaceae which vary as much in the relation of their sori to the margin as does *Nephrolepis*. The true relationship of all these species is shown much more clearly by the common apical position of their sori on the veins than by the relation of these sori to the leaf margin.

Let us further test the value of the marginal-superficial category of Bower and the apical-lateral interpretation presented here. *Oleandra* is a very natural genus whose relationship has always been doubtful. Bower, however, included the genus with his Davallioid ferns, a group forming a part of his Marginales line. The sori of *Oleandra* are neither marginal, intramarginal, or even medial; in all known species without exception the sori are costal, that is, located close to the midrib. Here the phylogenetic slide must have been complete! How very unnatural, then, to place *Oleandra* in the Marginales. On turning to a consideration of the position of the sori on the veins, we find that the sori of none of the oleandras are terminal on veins, in contrast to the universally apical sori of the Davalliaceae; rather they are all lateral on the veins and close to the midrib. It seems to be clear than *Oleandra* should neither be included with the Davallioid ferns nor placed in the Marginales, but rather that their affinity is with the Thelypteroid-Asplenioid ferns.

Although in a great majority of the ferns the sori are clearly either lateral or apical on the veins, there are some soral conditions which are very difficult to interpret. The distinction between the apical and lateral positions on veins disappears in two cases: first, if sori apical on the veins spread inward along the veins, and second, if sori lateral on the veins extend outward to the apex. Tryon (1942) has suggested the possible phyletic movement of the receptacle in the tribe Cheilantheae: "The receptacle can be thought of as having moved toward the vein-ends which were then correspondingly expanded, and finally to have spread laterally, the adjacent vein-ends connecting." He begins his series in this tribe with *Eunotholaena* in which the sporangia are on the terminal one-half or one-fourth

of the little-modified veins, and carries it through *Cheilanthes*, whose sporangia are on clavate or flabellate vein-ends, to *Doryopteris* in which the sporangia are borne on a continuous commissure connecting the vein-ends. Tryon interprets the series as a movement of the sori outward from the terminal portion of the veins to the enlarged and expanded vein-ends.

Chowdhury (1932), from the study of subdimorphic pinnae of *Osmunda claytoniana* and of extinct osmundaceous ferns, concluded that the primitive position of the sori of these ferns is superficial on the abaxial surface of the blade. But with the total failure of the fertile pinnae to expand, the sporangia appear to be marginal although actually they can be neither marginal nor superficial since there is no blade expansion. Chowdhury's conclusion that for the Osmundaceae the abaxial superficial position of the sori is primitive is directly opposite to the conclusion of Bower (1926) that the originally marginal sporangia passed to a superficial position on the abaxial surface. The writer agrees with Chowdhury and Harris (1931) that in this family the unspecialized members show the sori to be lateral on the veins and not apical or marginal

Is there any direct evidence to indicate whether the apparent spread of the sori has been toward or away from the apices of the veins? So far as the writer knows there is no direct evidence which tips the balance of decision one way or the other. Until something definite is known as to the nature of the control involved in sorus initiation, no satisfactory solution is likely to be forthcoming. Certainly it is unwise to prejudice the whole case by accepting the uncertain cladode theory of the leaf and the psilophytan ancestry of the ferns. Assuredly no appeal to "physiological advantage" can settle the question, as ferns with sori in all positions live side by side; one position would seem to be as good as another. Should the idea be true that there has been a movement of spore production from the center of the axis to the periphery of the sporophyte in the Metathallophyta, we could conclude that those sori which are apical on veins are advanced because they have reached the determinate limit of the movement toward the periphery of the plant body.

To summarize, then, ferns may be divided into two groups, the first characterized by sori borne laterally on the veins, their position ranging from very close to the midrib to the apex of the veins themselves. If the venation is reticulate, the sori may be at the point of union of veins. Probably derived from this group are the species with acrostichoid sori. The second group is characterized by sori normally located at the apices of veins which may or may not be expanded at the tip or be united by a vascular commissure. Certain ferns of this group which belong to the Polypodiaceae have veins which do not reach the leaf margin, Figs. 14–18, 20. The group also includes such families as the Dennstaedtiaceae, Lindsayaceae, Davalliaceae, Hypolepidaceae, Pteridaceae, Sinopteridaceae, and Adiantaceae in which all the veins reach the margin or equally near it.

17. Shape of the sorus. The sporangia of ferns are grouped in clusters called sori on circular, linear, or large and unrestricted receptacles. These receptacles are usually lateral or apical on veins, but in certain genera the receptacle may cover both veins and the epidermal tissue between them.

When the receptacle is small and circular, the sorus is punctiform. Should two or more receptacles occur so close together that their sporangia intermingle and appear to form one sorus, the resulting coenosorus is somewhat elongated as in *Bolbitis deltigera* (Wall.) C. Chr., *Drymoglossum*, and *Colysis*. Should the receptacle extend along a free vein, the sorus becomes linear as in *Asplenium* and *Diplazium*. If the receptacle extends along anastomosing veins, a reticulate sporangial pattern results as in *Hemionitis* and *Antrophyum*. If the receptacle extends along a vascular commissure connecting vein-ends, a continuous marginal sorus is formed. If the receptacle spreads from the veins to the adjacent epidermal

tissue as in *Acrostichum* and *Platycerium*, an acrostichoid sporangial pattern results.

Among the leptosporangiate ferns small receptacles on the veins may be considered primitive, and any fusion or elongation of receptacles, a derived condition. It is not to be inferred, however, from what has been said that soral shapes within genera are widely variable unless the occurrence of coenosori is sporadic or intermittent.

18. THE INDUSIUM. Indusia are of regular occurrence in such genera as *Asplenium* and *Oleandra;* in others indusia may be of specific rather than generic occurrence as in *Cyathea* and *Thelypteris*. No indusia at all occur in the ferns included in the Polypodioideae by Christensen (1938); in nearly all of these ferns paraphyses are intermixed with the sporangia. Still another group of ferns including the Pteridaceae, Sinopteridaceae, Adiantaceae, and Ceratopteridaceae has modified and reflexed leaf-margins called false indusia. But no matter what these indusial scales, hairs, or flaps may be called, they are all fundamentally the same in that they are sterile growths occurring in proximity to sporiferous areas. Such elaboration of tissue is common in the higher plants—sepals, petals, corona, etc., of flowers, and the elaborate vegetative growth associated with the inflorescence of the Araceae. Although indusia may "protect" young sporangia, they should not be thought of as having arisen in order to carry out that function, but rather as vegetative out-growths associated with the development of reproductive structures.

In the Hymenophyllaceae and the Davalliaceae the indusium arises below the receptacle which terminates a vein, and varies from scale-like with basal attachment, to half-cup-shaped or tubular with basal and lateral attachment. In punctiform sori which are lateral on veins, the indusia may be inferior and calyx-like as in *Cyathea*, lateral and scale-like as in *Cystopteris*, lateral and reniform as in *Dryopteris*, or superior and peltate as in *Polystichum*. In other sori which are lateral on veins but with more or less elongated receptacles, the indusia may be elongate-reniform as in *Mesochlaena*, elongate and mostly unilateral but often hooked over the vein as in *Athyrium*, or completely unilateral as in *Asplenium*.

Infolded leaf-margins occur irrespective of whether the sori are indusiate or not: both infolded margins and indusia may be present as in *Onoclea* and *Marsilea;* infolded margins but no indusia occur in *Pteris*, *Onychium* and *Ceratopteris*.

The presence of indusia in contrast to paraphyses indicates neither an advanced nor a primitive condition, but simply a different expression of vegetative growth which occurs in the neighborhood of reproductive centers. The elaboration is localized in the one case, and is scattered throughout the receptacle in the other.

19. THE ORDER OF SPORANGIAL DEVELOPMENT WITHIN THE SORUS. Bower (1923) recognizes in his main phyletic lines of the ferns three levels or conditions based on the order of development of the sporangia in the sorus: the Simplices, the Gradatae, and the Mixtae. He believes that these states of the sori "may severally have been achieved in accordance with biological advantage" along three distinct evolutionary lines. The Simplices include those ferns in which the sporangia develop simultaneously in any one sorus. The Gradatae are those ferns, in any one sorus of which the sporangia develop in basipetal or acropetal succession. The Mixtae are those in which the sporangia originate in irregular order.

Is this order of sporangial development of any phylogenetic value? The simultaneous development of sporangia occurs in the eusporangiate ferns and in such leptosporangiates as the Osmundaceae, Gleicheniaceae, Schizaeaceae, and Matoniaceae. These ferns are also characterized by their circular or elongated, unraised receptacles which bear from one to a few large sporangia. Of course where the sorus has but one sporangium as in *Lygodium* the order of development has no meaning. This simultaneous development of sporangia within each sorus

would seem to be a characteristic of those families which have a longer geologic history than the families in which the sporangia develop in succession. As a taxonomic character, therefore, soral development should take precedence over soral position which Bower uses to establish his three phyletic lines (Smith, 1938). In cases where simultaneous development is present in higher families, as in two genera of the Hymenophyllaceae, it is not associated with the same supplementary characters as those indicated for the more primitive families.

Bower's Gradatae and Mixtae really constitute but one group in which sporangial initiation and development is not simultaneous but rather successive. Species with a regular sequence of sporangial development are placed in the Gradatae; those in which "the sporangia of different ages are aggregated together without any definite sequence" are placed in the Mixtae. The essential similarity of the two groups is indicated by the fact that both regular and irregular sequences of development may be present in the same genus, as in *Dennstaedtia* or *Hypolepis*, and by the fact that in some ferns such as *Dennstaedtia rubiginosa*, *Cyrtomium* spp., and some of the Pteridaceae an initial regular sequence of development is followed by the interpolation of young sporangia in an unrecognized order.

The point to be emphasized is that receptacles of gradate sori are normally somewhat elongated-columnar as in *Trichomanes* and *Matteuccia*, peltate as in *Cyathea*, or dome-shaped as in some species of *Hymenophyllum* The acropetal or basipetal sequence in sporangial development seems to be expressed where some such elongation of the receptacle is present.

The receptacles of the "mixed" sori are normally flat or only slightly raised. No one physiological gradient from apex to base of the receptacle, or vice versa, seems to exist: the writer believes that a careful study of the development of these mixed sori should be made to determine if the pattern of succession of the sporangia is not unapparent rather than lacking as is true in a condensed cymose inflorescence.

For the present, therefore, it seems wise to give up the idea of three fundamentally different "soral states" suggested by Bower, and to think, rather, of two sections of the homosporous leptosporangiate ferns: the first with sori in which there is a simultaneous development of the sporangia, and the second with sori in which there is usually a successive development of sporangia. The first group is further characterized by sporangia which are large and relatively few per sorus, most of which also open by longitudinal dehiscence. The second group is usually characterized by sporangia which are relatively smaller and more numerous, which usually dehisce transversely.

Although it is unlikely that the group of ferns characterized by the simultaneous development of sporangia in the sorus has directly given rise to the group characterized by successive sporangial development, it seems tenable that the latter are more advanced than the former.

20. THE SPORANGIUM. It should be made clear at the outset that the beautifully perfect mechanism of the polypodioid type of sporangium has not arisen due to any continued experimentation on the part of the plant and subsequent selection of the most biologically advantageous forms. The oblique annulus of the Gradatae does not become vertical because "the oblique position would be mechanically inconvenient when the receptacle is flat" as suggested by Bower (1935), but rather heritable protoplasmic factors are responsible for the variation and modification of the fern annulus.

In that group of leptosporangiate ferns with simultaneous sporangial development, the annulus consists of a cluster of thick-walled cells located near the apex of the sporangium, as in the Osmundaceae, or of an apical ring with a 1-celled apical plate as in the Schizaeaceae, of a horizontal ring with a large apical plate as in the Gleicheniaceae, or of an irregular and variable incomplete ring as in the

Matoniaceae. Dehiscence is median longitudinal except in *Platyzoma* and *Matonia*. The sporangia are sessile or short-stalked, the stalks being more than three cells thick. The spore-output per sporangium (Bower, 1923) varies from 1024 to 16: in the Osmundaceae from 512–256, in the Schizaeaceae from 256–128, in the Gleicheniaceae from 1024–512 in *Gleichenia flabellata*, to 256 or less in *G. linearis*. In *Platyzoma* the spore-count varies from 32–16, but there is considerable doubt whether this genus really belongs in the Gleicheniaceae.

In that group of the leptosporangiate ferns with successive sporangial development, the annulus consists of a more or less complete ring which varies in orientation from oblique to vertical. This ring may be complete with either some or all of its cells thickened, or it may be incomplete and interrupted by the stalk of the sporangium. The thin-walled part of the ring, often forming the stomium, may be little modified or may be clearly specialized as lip-cells. Dehiscence is lateral and takes place in this thin-walled area, except in *Loxsoma*. The sporangial stalk varies from short to long, and is 4–3–1–cells thick. The spore-output per sporangium varies from 420 to 1: in the Hymenophyllaceae from 420–32, in the Cheiropleuriaceae 128, in the Cyathaeceae from 64–8, in most of the "Polypodiaceae" about 64, in the Sinopteridaceae from 64–12, in the Ceratopteridaceae from 32–16, and in the Marsilaeceae from 64 microspores to 1 megaspore.

In the past, sporangial characters have been largely used to segregate families. Most of the ferns that have a more or less complete vertical annulus have been put into the "Polypodiaceae." Actually there is a very marked variety in sporangial structure. For instance, the annulus is oblique in *Odontosoria retusa* (Cav.) J. Sm., complete and slightly oblique in *Polystichum deltodon* (Bak.) Diels and in *Neocheiropteris waltoni* Ching, complete except for the interruption by the stalk in *Cheiropleuria bicuspis* (Bl.) Presl, and very broad and exceedingly variable in *Ceratopteris*. In recent years the "Polypodiaceae" have been subdivided into many families, sometimes on the basis of sporangial characters but more often on other bases.

21. THE TIME OF SEXUAL DIMORPHISM. The time of appearance of sexual diversity in the life-cycle of plants varies at different levels of differentiation in the plant kingdom (Schaffner, 1923). At the most primitive level the appearance of sex differences takes place in the gametes themselves; their gametangia appear to be identical, as in the alga *Ulothrix*. The second level is that in which sex differences appear in the gametangia located on a common hermaphroditic prothallus, as in most homosporous ferns. The third level is that in which there are distinct male and female gametophytes as in the unisexual prothalli of *Onoclea* and *Matteuccia* (Mottier, 1910). A fourth level is that in which sex differentiation occurs at the initiation of the sporangia in the sorus. This results in the formation of micro- and megasporangia, and micro- and megaspores as in *Marsilea*. In the fifth level the differentiation occurs still earlier, at the initiation of the sorus, with the result that each sorus contains microspores or megaspores but not both. This occurs in *Salvinia* where the two kinds of sori are similar in appearance, and in *Azolla* where the sori are dissimilar. If sexual dimorphism began any earlier in the life-cycle, microsporophylls and megasporophylls would be formed, but this level has not been reached by any of the known ferns.

The preceding twenty-one patterns of variation occurring in the ferns provide a basis on which the ferns of Burma will be classified. It should be recognized, of course, that some of these patterns will be valuable primarily in the arrangement of species in their genera; this will be true especially of patterns of vegetative structures. Others, particularly those having to do with reproductive structures and the life-cycle, will be of use in working out the relationships of larger groups.

From such a review of the variations occurring in the leptosporangiate ferns certain deductions of phylogenetic interest may be drawn. (Cf. Schaffner, 1936.)

1. Phylogenetic development in general is not teleological and does not advance because of some assumed utility of organs or mechanisms.

2. Lamarkian and Darwinian evolutionary hypotheses receive no support from the detailed study of ferns.

3. There is no general correspondence between the taxonomic system and phylogenetic progress on the one hand, and environments on the other.

4. Phylogenetic development is postulated as the result of an intrinsic process which is dependent upon the fundamental organization of the protoplasm—a sort of "internal predestination."

5. Any one character may become more specialized while other important characters remain unchanged.

V. The Orders and Families of Ferns

Taxonomists who have contributed greatly in recent years to the understanding of the relationships of ferns include W. R. Maxon, E. B. Copeland, Carl Christensen, and R. C. Ching. Attention is particularly directed to Copeland's treatise, *The Oriental Genera of Polypodiaceae* (1929), to Christensen's most valuable revision of the Filicinae in Verdoorn's *Manual of Pteriodology* (1938), and to Ching's publication, *On Natural Classification of the Family "Polypodiaceae"* (1940b).

In the present study the fern families are placed in five orders, the Ophioglossales, Marattiales, Filicales, Marsileales, and Salviniales, as shown in Chart IV on page 105. In the past the family Marsileaceae has either been included with the Salviniaceae and Azollaceae in a separate order, the Hydropteridales, or has been included in the Filicales. Campbell (1904), Bower (1926), and Christensen (1938) have considered that the Marsileaceae are descended from Schizaeaceous stock. Eames (1936) agreed in general with this view but suggested that the family may have been derived from Gleicheniaceous ancestors. Smith (1938) thought that the Marsileaceae could not have been derived from the Schizaeaceae, and that their origin should be sought among the Hymenophyllaceae or the Cyatheaceae. To connect the Marsileaceae with any homosporous fern family is to assume a degree of change in heritable characters quite beyond that which a study of genetics would lead us to expect. It is wisest to place the Marsileaceae in a separate order, making no guesses at present as to the definite origin of this family.

The order Filicales, as here delimited, includes only the homosporous leptosporangiate ferns. Linnaeus (1753) classified the 190 known homosporous species of ferns under ten genera—*Osmunda, Onoclea, Acrostichum, Hemionitis, Polypodium, Asplenium, Pteris, Blechnum, Lonchitis*, and *Trichomanes*. As more and more ferns became known, most of these original genera became the bases of families. Presl, a century after Linnaeus (1850), classified the then known homosporous leptosporangiate ferns under 149 genera and 17 tribes or families. Although 5663 ferns belonging to the Filicales were known by 1906, Christensen classified them under only 136 genera and 8 families. We see here, linked with a three-fold increase in the number of species known, a reduction of over 50% in the number of families recognized. By 1938 Christensen recognized 9000 species and 200 genera belonging to the Filicales which he classified under 11 families, one of which, the "Polypodiaceae," he subdivided into 15 subfamilies; these, he suggested, might better be dealt with as families. Ching (1940), following this suggestion, divided the "Polypodiaceae" into 32 sections, to each of which he gave a family status. This is a large increase in the number of fern families, but it is in harmony with the present trend in splitting large and unwieldy taxonomic groups into smaller ones; for example, Copeland (1938) divided the species of the family Hymenophyllaceae into 33 genera in place of the two usually recognized.

Some of the families proposed by Ching will likely stand as natural groups, but not all of them. For instance, the Sphaerostephanaceae which Ching based on *Sphaerostephanos* J. Sm. (or *Mesochlaena* R. Br.) cannot stand. Smith, himself, (1841), repudiated his genus as having been founded on a misconception of the nature of the receptacle. Ching's "Sphaerostephanaceae" is based on the same misconception and must therefore be repudiated. Copeland (1941c) pointed out several other families which he considered to be unnatural, but for the present the writer is accepting 31 of the families which Ching has revived or proposed anew.

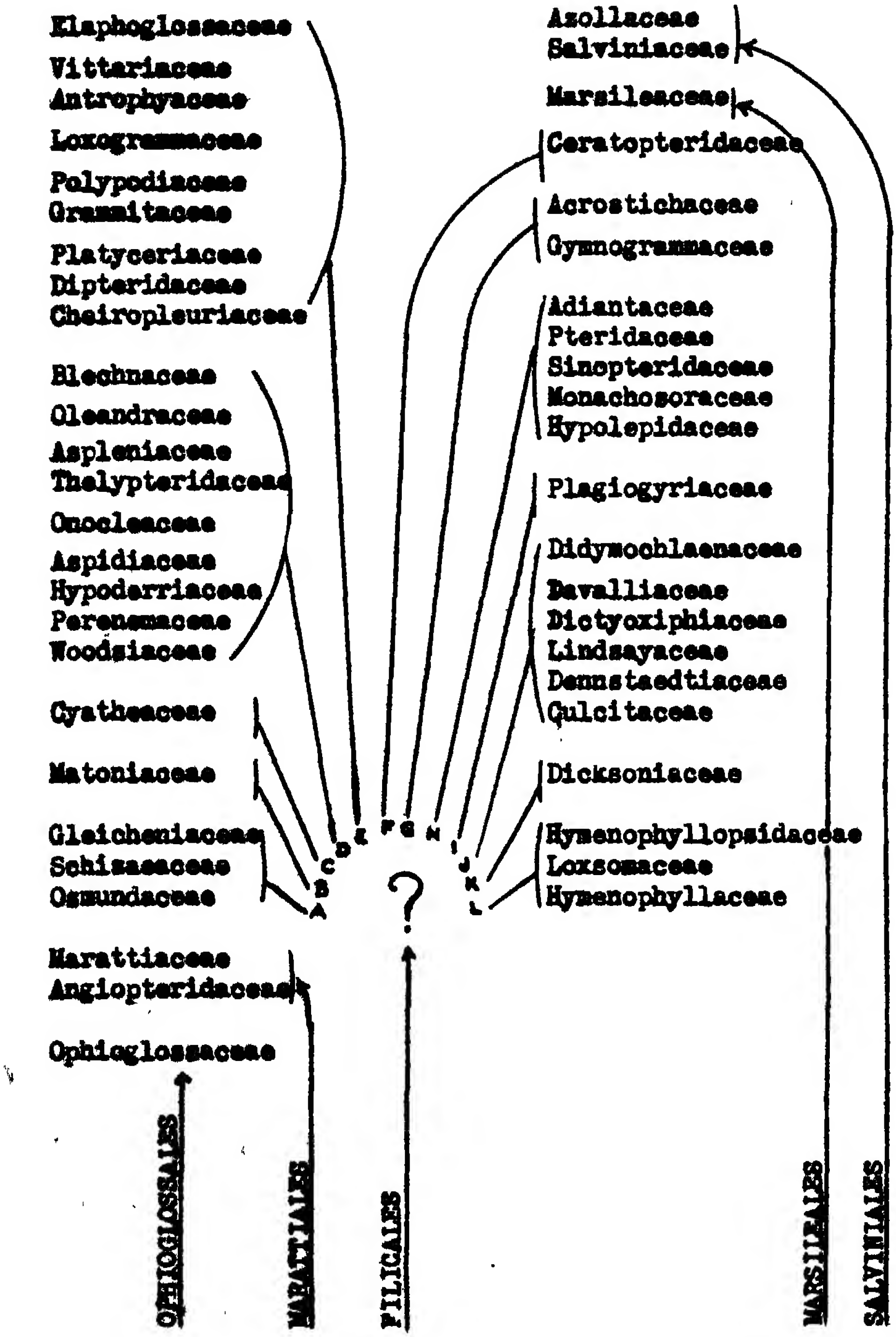
Bower, and following him Eames, Smith, and Campbell, have considered the "Polypodiaceae" to be polyphyletic. The Davallioid and Pteroid sections of the family they considered to have evolved from the Dicksoniaceae, and this family in turn from the Schizaeaceae. The Gymnogrammeoid ferns they believed to have originated from the Plagiogyriaceae, and this family from the Osmundaceae. The Asplenioid, Dryopteroid, Woodsioid, Onocleoid, and Blechnoid sections of the Polypodiaceae they considered to have originated from the Cyatheaceae, and this family from the Gleicheniaceae. The Dipteroid section they supposed to have originated from the Gleicheniaceae through the Dipteridaceae.

To some extent Ching, too, has been influenced by this polyphyletic concept. He arranges the 32 families segregated from the "Polypodiaceae" in six phyletic series as follows: first, a Lindsayoid-Devallioid series originating from Dicksonioid stock; second, a Pteroid-Gymnogrammeoid series originating from a similar ancestral stock; third, a Thelypteroid-Asplenioid series, with the Blechnoid ferns as an offshoot, originating from some extinct and unknown stock; fourth, a Cyatheoid-Aspidioid series originating from Cyatheoid stock; fifth, a Dipteroid-Polypodioid series, with the Elaphoglossaceae as an offshoot, originating from Dipteroid stock; and sixth, an isolated family, Didymochlaenaceae, originating from unknown stock.

The weak point of these theories which postulate the polyphyletic origin of the "Polypodiaceae" is the large amount of parallel development which they have to assume. How does it happen that all phyletic lines develop the same type of sporangium? As pointed out by C. A. Weatherby, we have been accustomed to think of evolution as largely a process of diversification; why, then, have these ferns produced a series of end members more alike than their ancestors were, and yet are to be kept wide apart because their ancestors are considered to have been different?

Actually there is little evidence to indicate that Bower's "Simplices"—the Schizaeaceae, Osmundaceae, and Gleicheniaceae—are really parent stocks which have given rise to three separate phyletic lines of ferns, of which each in turn gave rise to certain sections of the "Polypodiaceae."

In Chart IV the writer has arranged the families of the Filicales in generally related groups, without implying anything as to their origin. The ferns in Groups A–E are characterized by sporangia located in sori which are lateral on the veins on the abaxial side of the leaf. Group A includes ferns which are further characterized by exindusiate sori in which the sporangia develop simultaneously and dehisce longitudinally. Group B is further characterized by sori with superior peltate indusia, and by sporangia which develop simultaneously and dehisce laterally. Group C includes tree ferns with either exindusiate or indusiate sori. If present, the indusium is inferior and cup-like. The sporangia develop simultaneously in species having flat receptacles, and successively in species with elongated receptacles; the annulus is oblique and the dehiscence lateral. Group D includes those non-tree fern families, which normally have indusiate sori in which the sporangia develop successively. The sporangia have a more or less complete vertical annulus and dehisce laterally. Group E includes those non-tree fern



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families which normally have exindusiate, paraphysate sori in which the sporangia develop successively and have a more or less complete vertical annulus and lateral dehiscence.

The families in Groups H–L are characterized by sori located at the apices of veins. Group L includes those ferns in which the sporangia are borne on more or less cylindrical receptacles usually with basal intercallary meristems. The development of the sporangia on the receptacle is usually basipetal, and the dehiscence, usually lateral. Group K includes those tree ferns having thick, erect or decumbent stems, sori with inferior cup-shaped or 2-lipped indusia, and sporangia with oblique annulus and basipetal development. Group J includes non-tree fern families which are usually characterized by sori each subtended on the basal side by a scale-like or half-cup-like indusium, by sporangia with more or less vertical annulus and successive development. Groups H and I are characterized by sori which are not subtended by indusia as above. The sporangia may be apical or may extend from the apices of the veins back along the veins for a short distance. The margins of the fertile leaves are usually reflexed over the sori. Group I is further characterized by sporangia with oblique annulus; Group H by sporangia with more or less vertical annulus.

The families in Groups F and G are characterized by lack of indusia, and by sporangia scattered on elongate receptacles which follow the veins and which sometimes extend to the epidermal tissue between the veins. Group G is further characterized by having no reflexed leaf margin, and by sporangia of the normal polypodioid type. Group F, on the other hand, is characterized by reflexed colorless leaf margins, and by very large sporangia with broad and variable annulus, located very far apart on the veins.

It is not to be inferred from Chart IV that the families in each group evolved in the order in which they are listed, nor that families originated from the immediately preceding ones on the chart. The grouping merely shows possible general relationships among the families of ferns and possible lines of diversification within the order Filicales.

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Reptiles of the Pacific World

This book is one of a series of seven books on the Pacific World, published under the auspices of the American Committee for International Wild Life Protection. Though it covers a wide field, it is a very readable and useful book.

There are separate chapters on the various groups of reptiles occurring in the Pacific area, chapters on poisonous snakes and the treatment of snake bite, a chapter on Pacific amphibians, and two chapters on collecting, preserving, and shipping specimens. At the end of the book is a chart showing the distribution in the Pacific of the various families of reptiles and amphibians, and a brief bibliography. The book contains numerous keys, and there are 70 line drawings illustrating the characters used in the keys. A great deal of space is devoted to accounts of the habits of the groups treated.

Except in a few groups, no attempt is made to present a complete taxonomic account of the Pacific forms. However, the reader will be able to identify a Pacific reptile or amphibian down to family, and often farther. The distribution chart will enable one to quickly determine what forms to expect in any island group, though it omits a few cases of introduced species. To many readers the most interesting parts of this book will be the accounts of the habits of the types discussed.

It is unfortunate that this book did not appear a few years ago when so many military personnel were going to Pacific areas. However, those who have spent time in the Pacific will find this book particularly interesting.—*D. J. Borror.*

Reptiles of the Pacific World, by Arthur Loveridge. The Macmillan Company, New York, 1945. xii+259 pp. $3.00.

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THE FERNS OF BURMA[1]

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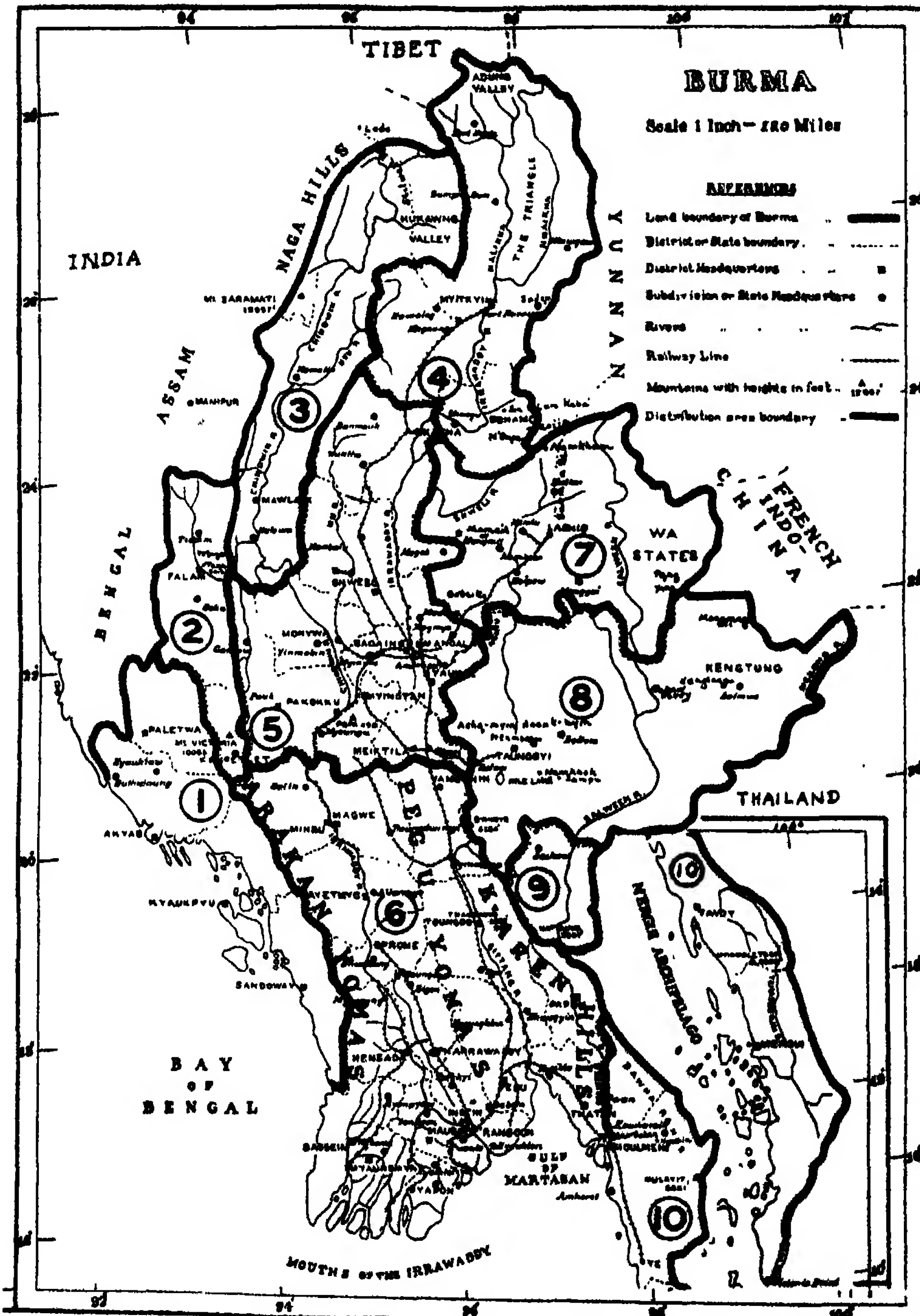
Burma, with rainfalls in its various districts of 20 to 225 inches from June to October and with habitats from sea level up to 18,000 feet, has a very rich fern flora. During the hundred years previous to 1920 fern study was confined almost entirely to the Pegu and Tenasserim Districts of lower Burma, but with the Joseph H. Rock collection of 1920–1924 from upper Burma, western China, and northern Siam, came the first accurate concept of the richness and variety of the ferns of upper Burma.

In 1931 the C. Snydam Cutting Sikkim Expedition of the Field Museum brought back about 25 fern specimens from the Burma-Tibet frontier. In 1937 the Vernay-Cutting Expedition of the New York Botanic Garden and the Natural History Museum collected in upper Burma and added two ferns to the Burma list. In 1943 Harold Young collected over a hundred ferns along the Stilwell Road near the Assam-Burma border, of which twenty were new records for Burma. The writer named the ferns collected by the Cutting Sikkim Expedition and by Harold Young. From 1930 to 1942 the writer has collected over 325 kinds of ferns in various parts of Burma. The total number of ferns reported to date for the country is 460, which belong to 104 genera. The writer's main collection is in the Herbarium of Judson College, Rangoon, Burma; duplicates of some numbers have been distributed to Gordon College, Rawalpindi, India, to Ohio State University, and to the Arnold Arboretum under whose auspices a part of the collecting was done. Numbers cited in the following enumeration refer to the writer's specimens, unless another collector's name is given.

Burma is so located that many ferns of both the China-Himalayan and the Malayan regions occur in the country. Of the 460 ferns reported for Burma, 125 are to be found also in that part of the Malay Peninsula which is under British protection, south of latitude 6.5° N. This is particularly remarkable because Burma lies north of the area having both summer and winter rains; in Burma the dry season lasts from the middle of October to the end of May. This long dry period must effectively limit the northward migration and establishment of many Malayan species whose ecological amplitude is not sufficient to permit them to survive the long dry season. An unpublished list of the ferns of the Malay Peninsula compiled in 1937 by R. E. Holttum of the Singapore Botanic Garden reports 419 ferns as occurring south of latitude 6.5° N.

Of the 125 ferns common to both Malaya and Burma some are cosmopolitan species such as ***Adiantum capillus-veneris***, ***Osmunda regalis***, ***Pteridium aquilinum***, and ***Pteris vittata***. Others are pantropic such as ***Asplenium cuneatum***, ***Didymochlaena truncatula***, ***Dryopteris paleacea***, ***Elaphoglossum petiolatum***, ***Histiopteris incisa***,

[1]Papers from the Department of Botany, The Ohio State University, No. 491.



Map of Burma showing areas referred to in the text: 1, Arakan; 2, Chin Hills; 3, Upper Chindwin; 4, North-east Burma; 5, Central Burma; 6, Southern Burma; 7, Northern Shan States; 8, Southern Shan States; 9, Karenni, 10, Tenasserim.

Mecodium polyanthos, *Mephrolepis biserrata*, *N. cordifolia*, *N. exaltata* (*falcata*), *Pityrogramma calomelanos*, *Pteris biaurita*, and *Pteris quadriaurita*. There are rather more species common to Burma and Malaya which may also be found in Madagascar and (or) South Africa (Christensen 1932): this group includes *Adiantum caudatum*, *A. philippense*, *Asplenium adiantoides*, *A macrophyllum*, *A. normale*, *A. unilaterale*, *Ceratopteris thalictroides*, *Crepidomanes bipunctatum*, *Davallia denticulata*, *Dicranopteris linearis*, *Lindcaya cultrata*, *Microsorium punctatum*, *Ophioglossum pedunculosum*, *O. pendulum*, *Schizoloma ensifolia*, *Stenoloma chusanum*, *Thamnopteris nidus*, and *Vittaria scolopendrina*.

The following genera which have representatives in the Burma flora are absent from Holttum's list of peninsular species: *Arthromeris*, *Azolla*, *Botrychium*, *Colysis*, *Cryptogramma*, *Ctenitis*, *Cyclopeltis*, *Cyrtomium*, *Davallodes*, *Diplaziopsis*, *Goniopteris*, *Lemmaphyllum*, *Marsilea*, *Microchlaena*, *Monachosorum*, *Neocheiropteris*, *Onychium*, *Salvinia*, *Selliguea*, and *Woodwardia*. In addition to these genera the Burma flora is much richer than the Malayan in *Cheilanthes*, *Dryopteris* sensu propria, *Lepisorus*, *Phymatodes*, *Polypodium* sensus propria, and *Polystichum*. The above 26 genera together with many others are widely distributed from northern India across Burma to southwestern and central China. The frequency of this distribution is emphasized by Ching's revisions of the genera "Dryopteris" and "Polypodium" of the China and Sikkim-Himalayan areas (1933b, 1933c, 1933d, 1934b, 1935c, 1936b, 1936c, 1938a, 1938b, 1938c, 1941c). These studies indicate essential similarity of the fern flora throughout the eastern Himalayas, Burma, and southwestern and central China. Since Burma is situated at the northwestern end of the Malaya Peninsula, and at the junction of the east-west ranges of the Indian Himalayas and the north-south ranges of Tibet and western China, the Burma fern flora is composed of species of these vast areas. Present records indicate that the northern species predominate over the southern species about 3 to 1.

KEY TO THE GENERA OF THE FERNS OF BURMA

1. Aquatic ferns 2
1. Not water ferns 5
    2. Leaflets 4, clover-like .... 102. **Marsilea**
    2. Leaf blade not like a 4-leaf clover 3
3. Leaves relatively large (6–18 in.), pinnatifid or compound; vegetative budding from the leaflet axils or sinuses; rooted or free floating........ 101. **Ceratopteris**
3. Leaves either minute or up to an inch long, entire, leaf margins not budding; free floating. 4
    4. Leaves in whorls of 3, the upper 2 very hairy and floating, the third submerged and root-like .... 103. **Salvinia**
    4. With very minute leaves closely placed on a branched stem, only slightly hairy; no dissected root-like leaf .... 104. **Azolla**
5. Leaves simple, margin entire or nearly so 6
5 Leaves simple but dichotomously forked or palmately lobed........ 29
5. Leaves pinnatifid or compound........ 31
    6. Sporangia on narrow spike-like sporangiophores arising from the base or apex of the sterile part of blade........ 7
    6. Sporangia not as above........ 9
7. Sporangiophore arising from the base of the sterile part of blade; no annulus on the sporangia........ 1. **Ophioglossum**
7. Sporangiophores arising from the apex of the sterile part of blade........ 8
    8. Sterile part of blade grass-like; sporangia in digitate or pinnate tassels; annulus around the pointed apex of the large sporangia........ 6. **Schizaea**
    8. Sterile part of blade not grass-like; sporangia small, on the very much narrowed, prolonged apex of the leaf; sporangia polypodioid........ 49. **Hymenolepis**

9. Sporangia not in sori but covering back of blade, or so close together that they do not appear to be in sori 10
9. Sporangia in marginal or linear sori, or following reticulate veins 12
9. Sori round or roundish, sometimes very close together and almost hidden by stellate hairs, 22
  10. Veins free, simple or forked . . . . 64. **Elaphoglossum**
  10. Veins anastomosing or reticulate 11
11. Fertile leaf narrowly linear and entirely fertile; no stellate hairs . . . . 55. **Leptochilus**
11. Sporophylls usually not contracted; stellate hairs abundant, almost hiding sori, 59. **Pyrrhosia**
  12. Sori linear, parallel to margin (intramarginal) or marginal 13
  12. Sporangia forming a network along reticulate veins 16
  12. Sori oblique to the midrib 17
13. Leaves dimorphic 14
13. Leaves uniform 15
  14. Epiphytic, sporophylls linear . . . . 60. **Drymoglossum**
  14. Terrestrial, sporophylls deeply lobed and long petioled . . . . . . 90. **Doryopteris**
15. Linear sorus sunk in a groove at or near margin; blade grass-like . . . . . . 63. **Vittaria**
15. Linear sorus 1–2 mm. inward from each margin, not sunk in grooves . . 48. **Lepisorus** (part)
  16. Petiole of fertile leaf much elongated, polished . . . . 99. **Hemionitis**
  16. Petiole of fertile leaf like that of sterile, not elongated . . . . . . 62. **Antrophyum**
17. Indusium present 18
17. Indusium lacking 20
  18. Veins free 19
  18. Veins united by a marginal vein . . . . 37. **Thamnopteris**
19. Sori in opposite pairs on adjacent veins, their indusia opening toward each other, often finally confluent . . . . 36. **Phyllitis**
19 Sori not normally twinned in opposite pairs, single . . . . 38. **Asplenium**
  20. Without (or with very few) included veinlets . . . . 61. **Loxogramme**
  20. Free included veinlets present in the areoles 21
21. Leaves herbaceous; lateral main veins flexuous and poorly developed; rhizome subhypogaeous . . . . 54. **Colysis**
21. Leaves thick, rigid, glossy; lateral veins strong, raised, straight, reaching the margin; rhizome epigaeous, creeping . . . . 52. **Selliguea**
  22. Sori not on the end of veins or at the margin; blade more than 1 cell thick 23
  22. Sori on the end of veins or at the margin in cup or tubelike cavities; blade 1 to few cells thick . . . . 70. **Microgonium**
23. Sori in 1 row (rarely 2) between the midrib and margin 24
23. Sori in several rows between the main lateral veins or irregular; sometimes uniseriate in *Neocheiropteris ensata* 27
  24. Indusium present; venation free, forked . . . . 40. **Oleandra**
  24. Indusium lacking; venation not free 25
25. Rhizome thick, fleshy, creeping; blades coriaceous, usually pinnatifid; venation drynarioid or goniophlebioid, main laterals distinct . . . . 51. **Phymatodes**
25. Rhizome creeping but not very fleshy; blades usually simple 26
  26. Rhizome slender, wide-creeping, subnaked; leaves distant, glabrous, fleshy, usually dimorphic . . . . 50. **Lemmaphyllum**
  26. Rhizome usually short creeping, very scaly; leaves fairly close, coriaceous or papery, generally uniform . . . . 48. **Lepisorus**
27. Leaves bearing stellate hairs; sori close together, sometimes almost hidden by the stellate hairs . . . . 59. **Pyrrhosia**
27. Leaves without stellate hairs; sori distant 28
  28. Rhizome hypogaeous, thick, fleshy, densely scaly with a tuft of unicellular brown hairs at point of attachment; sori covered when young with large, fuscous, clathrate, peltate scales . . . . 47. **Neocheiropteris**
  28. Rhizome wide-creeping or scandent; no tuft of unicellular brown hairs at point of attachment of rhizome scales; clathrate, peltate scales in sori usually lacking, 53. **Microsorium**

29. Leaf blade ½ in. each way, thinly membranous . . . . **Gonocormus**
29. Leaf blade much larger, much thicker texture 30
 30. Epiphyte; leaf large, often dichotomously branched; sporangia crowded on soriferous disc . . . . **44. Platycerium**
 30. Terrestrial fern, palmately lobed; sori in a continuous marginal line . . **90. Doryopteris**

LEAVES PINNATIFID OR COMPOUND

31. Sori surficial 32
31. Sori marginal, or in spike-like, panicle-like, or strobilus-like arrangement . . . 33
 32. Sporangia spread over part of all the surface, not in sori (acrostichoid) . . . 34
 32. Sporangia in definite elongate sori 40
 32. Sporangia in round or roundish sori 53
33. Sporangia in marginal sori 82
33. Sporangia in spike-like, panicle-like, or strobilus-like arrangement 101
 34. Sporangia on apical pinnae, other pinnae sterile . . . . **100. Acrostichum**
 34. Sporangia on partially or wholly fertile leaves; other leaves sterile 35
35. Scandent fern, margin of leaflets cartilagenous, pinnae articulate with the rachis; veins parallel . . . . **24. Stenochlaena**
35. Scandent, margins not cartilagenous; veins reticulate . . . . **25. Lomagramma**
35. Not scandent, terrestrial, exindusiate 36
 36. Leaves bipinnate with white powdery coating on the under surface, **98. Pityrogramma**
 36. Leaves pinnate or pinnatfid, without powdery coating 37
37. Rhizome erect or suberect, sometimes several feet tall 38
37. Rhizome creeping, usually short 39
 38. Base of petioles covered with scales 1 in. long; base of pinnae cordate; caudex several inches thick . . . . **43. Brainea**
 38. Base of petioles enlarged and flat on adaxial face; base of pinnae not cordate, no long scales . . . . **85. Plagioyria**
39. Veins free . . . . **21. Egenolfia**
39. Veins anastomosing . . . . **23. Bolbitis**

SPORANGIA IN DEFINITE ELONGATE SORI ON ABAXIAL SURFACE

 40. Sori apparently parallel to the midribs and margins 41
 40. Sori oblique to the midribs 47
41. Venation free 42
41. Venation reticulate 45
 42. Leaf palmately compound (dichtomously divided) . . . . **Actiniopteris**
 42. Leaf pinnatifid or pinnate 43
43. 3- or 4-pinnatifid, fertile segments narrow, podlike, sori covering most of segment at maturity 44
43. Pinnate or pinnatifid; sorus contiguous to midrib, not near the margin . . . . **41. Blechnum**
 44. Vascular commisure connecting vein ends; leaves more than 5 in. long . **91. Omychium**
 44. Without commisure; leaves usually less than 5 in. long . . . . . . **88. Cryptogramma**
45. Fertile segments narrow; reflexed leaf margins meeting at the midrib; aquatic fern, **101. Ceratopteris**
45. Fertile pinnae not narrowed; sori not covering the whole blade; not aquatic ferns . . . 46
 46. Sori short, linear, contiguous with midribs; indusium present . . . . **42. Woodwardia**
 46. Sori the length of the pinnae, half way between midrib and margin . **96. Taenitis**
47. Without indusium 48
47. Usually with indusium 50
 48. Veins anastomosing with free included veinlets . . . . **54. Colysis**
 48. Veins parallel and very close, branching once or twice 49
49. Sori following the veins from midrib nearly to margin; distinct hydathodes near margin, **97. Conglogramme**

49. Sori following veins with sporangia in 2 rows, near the margin but not extending to midrib; sori make line parallel with margin; huge fern; stipules fleshy.... **4. Angiopteris**
   50. Sori all simple, never curved across a vein; lumen in cells of scales hyaline (clear), **38. Asplenium**
   50. Sori sometimes bent across a vein; delicate ferns; lumen in cells of scales pigmented, **32. Athyrium**
   50. Sori sometimes double; coarse ferns; lumen in cells of scales pigmented 51
51. Veins anastomosing ....35. **Diplaziopsis**
51. Veins free ..... 34. **Diplazium**

SPORANGIA IN ROUND OR ROUNDISH SORI ON ABAXIAL SURFACE

53. Tree ferns 54
53. Not tree ferns 55
   54. With costal areoles and free excurrent veins ... ..43. **Brainea**
   54. Without costal areoles. . .... 10. **Cyathea**
55. Rachis of leaves dichotomously branched, often a dormant bud in axil or branching; annulus transverse; sporangia sessile.......56
55 Not dichotomously branched; annulus neither transverse nor oblique; sporangia not sessile.......57
   56. Leaves 1-pinnate (pectinate) above highest fork. Rhizome slender, hairy; blade of indefinite growth with pair of stipule-like pinnae at the forkings; veins 3–6 forked in each group; 6–12 sporangia per sorus....... ....8. **Dicranopteris**
   56. Leaves bipinnate above last fork. Rhizome often ½ in. thick, densely scaly, blade of definite growth, no stipule-like pinnae at the sides of the forking; veins once forked; 2–6 sporangia per sorus ... 9 **Hicriopteris**
57. Indusium lacking or quickly fugaceous 58
57. Indusium present, persistent.......68
   58. Leaves pinnatifid or pinnate.......59
   58. Leaves slightly bipinnatifid to decompound.......64
59. Veins free and forked, or anastomosing to form 1 row (rarely 2) of subhexagonal costal areolae each with a simple excurrent soriferous veinlet. ....46. **Polypodium**
59. Veins copiously reticulate forming many rows of small areoles with included veinlets....60
59. Veins anastomosing by opposite pairs 67
   60. Some vegetative leaves wholly modified and humus collecting .. ... 58. **Drynaria**
   60. No vegetative leaves entirely modified nor humus collecting.......61
61. Very large leaves (± 3 ft. long) with base of the petioles expanded and humus collecting (no distinct petiole) ....57. **Pseudodrynaria**
61. Leaves with distinct petioles, or sessile, but base not modified and humus collecting. ...62
   62. Blade generally pinnate (juvenile forms simple) with articulated pinnae, **56. Arthromeris**
   62. Blade simple, pinnatifid (rarely pinnate but if so, pinnae not articulate to rachis)..63
63. Leaf generally coriaceous, simple or pinnatifid with principal nerves reticulate, distinct; often dimorphous, sori in 1–2 rows between main veins; plant glabrous..51. **Phymatodes**
63. Leaf generally thin, entire (rarely pinnatifid), uniform, without distinct principal nerves; sori small, scattered irregularly, round, rarely in 7–8 regular rows.. .53. **Microsorium**
   64. One vein in each ultimate leaf segment.......86. **Monachosorum**
   64. More than 1 vein in each ultimate leaf segment.......65
65. Veins usually reticulate or anastomosing.......67
65. Veins free or with costal arch.......66
   66. Habit of finely divided *Pteridium aquilinum*; leaf hairy on both surfaces; no tooth in sinuses.......49. **Hypolepis**
   66. Habit of *Pteris quadriaurita*; a tooth in each sinus....... .19. **Pteridrys**
67. Free included veinlets present.......22. **Tectaria**

67. Without free included veinlets. 105
68. Indusium inferior, globose, entire. . . . . 11. **Diacalpe**
68. Indusium peltate, reinform, or half cup-shaped 69
69. Veins anastomosing or reticulate. 70
69. Veins free. 72
70. Without free included veinlets 105
70. With free included veinlets. 71
71. Small irregular areoles, included veinlets pointing in all directions. . . . 22. **Tectaria**
71. Larger subhexagonal areoles formed by repeated dichotomous branching of the veins; free included veinlets pointed in one direction only; sori in 1 or 2 lines, parallel with the midrib. . . . . .17. **Cyrtomium**
72. Terrestrial (or if epiphytic, then pinnae articulate to rachis). 73
72. Epiphytic. 79
73. Pinnae or pinnules articulate to the rachis. 74
73. Pinnae not articulate to the rachis. 75
74. Indusium oblong, attached longitudinally; leaf bipinnate 84 **Didymochlaena**
74. Indusium reniform; leaf pinnate . . . . 83. **Nephrolepis**
75 Indusium suborbicular or scale-like, inserted under the base of sorus; long, weak, jointed hairs on costa, rachis and pinnules; veins reaching the margin . . . . . 33. **Cystopteris**
75. Indusium reniform. 76
75. Indusium peltate. 77
75. Indusium fixed by base and sides 78
76. Davallioid ferns, leaf pinnately decompound, pinnules in general rhomboidal in outline; rhizome creeping . . . . 80. **Leucostegia**
76. Dryopteroid ferns, leaves not with decompound ultimate rhomboidal segments. 112
77. Sori in 1-3 rows on each side of midrib and parallel to it; petiole fibrillose at the base; pinnae nearly entire, cordate or truncate at the base . . . . .15. **Cyclopeltis**
77. Sori in 1 row; pinnae enlarged on acroscopic side of the base, toothed; petiole scaly, 14. **Polystichum**
78. Stem erect; rachis nodose above at the insertion of pinnae; wide scales beneath at the base of each pinna; like Cystopteris but here veins do not reach the margin, 79. **Acrophorpus**
78. Stem creeping. . . . . **Microlepia**
79. Leaves once pinnate, leaflets articulate to rachis. . . . . .83. **Nephrolepis**
79. Leaves several times pinnate, leaflets not articulate to rachis 80
80. Leaves thin, pubescent, not deltoid; rhizome scales needle-pointed and mostly black . . . . .78. **Davallodes**
80. Leaves coriaceous or herbaceous, glabrous, often deltoid; rhizome scales not black, but brown or grey. 81
81. Indusium thin, free except at the base . . . . .80. **Leucostegia**
81. Indusium broad, firm to coriaceous, attached by base only; rhizome scales not ciliate (or but slightly so). . . . . .81. **Humata**
81. Indusium attached at sides and base; rhizome scales ciliate with peltate, persistent bases. . . . . 82. **Davallia**
85. Walls of cells thick, coarsely pitted . . . . 69. **Meringium**

SPORANGIA IN MARGINAL SORI: ROUND, CUP-SHAPED, CONTINUOUS OR INTERRUPTED

82. Leaves so thin that there is no differentiation of foliar tissues. 83
82. Leaves thick enough to have epidermis and other tissues. 91
83. Indusium valvate. 84
83. Indusium tubular or obconic, not valvate 87
84. Margin entire and naked. 85
84. Margin toothed. 86

85. Walls of cells not coarsely pitted........................ . ...**68. Mecodium**
86. Receptacle long, extruded; base of indusium obconic.. ....**69. Meringium**
86. Receptacle not long-exserted. ....**67. Hymenophyllum**
87. Rhizome filiform, leaves remote ... .88
87. Rhizome stout or fronds clustered 90
88. False veinlets present... 89
88. False veinlets absent, segments 1-nerved....... . . ..**71. Vandenboschia**
89. Fronds pinnately divided or compound.... . . . .**66. Crepidomanes**
89. Fronds simple or lobed, with marginal vein .. ..**70. Microgonium**
90. Fronds 1-pinnate, oriental....... . .. .**64. Cephalomanes**
90. Fronds bipinnatifid to decompound... ....**71. Vandenboschia**
91. Indusium distinctly 2-valved, rhizome covered with long, red, hair-scales; very large fern.... ....**72. Cibotium**
91. Indusium opening along or towards margin......... 92
91. Indusium or marginal flap opening away from margin..... 95
92. Sori usually continuous; leaf at most bipinnate... 93
92. Sori more or less round; leaf more compound.......... 94
93. Leaflets cut away on the lower side; veins free, forking.... . . ..**75. Lindsaya**
93. Veins anastomosing....... ....**76. Schizoloma**
94. Leaflets cuneate.. ....**77. Stenoloma**
94. Leaflets not cuneate (look out for *Davallia* and *Asplenium* with sori dorsal but indusia reaching the margin)... ....**75. Dennstaedtia**
95 Leaves seriate on a creeping rhizome..... 96
95. Leaves clustered.......... 98
96. Veins anastomosing with costal areoles. ....**93. Histiopteris**
96. Veins free or with marginal vein ... .97
97 Sori round on tips of free veins.. ....**87. Hypolepis**
97. Sori continuous, on marginal vein connecting free vein tips........ ......**92. Pteridium**
98. Petioles dark, polished.... 99
98. Petioles not polished...... 100
99. Sori on the inside of the reflexed leaf margin; leaflets cut away on the lower side, no white powder on under surface. ....**95. Adiantum**
99. Sori on the tips of free veins, not on the reflexed margin; leaflets pinnatifid; usually white powder on under surface....... ... .**89. Cheilanthes**
100. Sori never reach the midrib; coarse ferns...........................**94. Pteris**
100. Sori apparently from margin to midrib; leaf very decompound ....**91. Onychium**

Sporangia in Spike-Like, Strobilus-Like, or Panicle-Like Arrangement

101. Climbing ferns, sporangia in strobilus-like marginal lobes or pinnae, with scale-like indusia covering each sporangium.................................**7. Lygodium**
101. Not climbing, sporangia not in marginal strobili.......... 102
102. Veins reticulate, leaf simple, entire; sporangia in two rows in a narrow close spike; no annulus..**1. Ophioglossum**
102. Veins free, leaves not simple, or if simple, then grass-like......................103
103. Sterile part of leaf palmately compound; long loose spike-like sporangiophore arising from the base of the sterile blade; sporangia in crested loose clusters, **3. Helminthostachys**
103. Sterile part of leaf grass-like, linear, or dichotomously branched; sporangia in 2–4 rows covering one side of close distichous spikes at apex of sterile blade........**6. Schizaea**
103. Sterile part of leaf pinnate to repeatedly pinnatifidly compound........... 104
104. The entirely fertile pinnae never long-stalked.........................**5. Osmunda**
104. The fertile pinnae always long-stalked sporangiophores.............**2. Botrychium**

GENERA SEPARATED FROM "DRYOPTERIS" AND "POLYSTICHUM" BY CHING AND CHRISTENSEN

105. Veins free (simple or forking, or with costal arch) 106
105 Veins, at least the lowest, anastomosing by opposite pairs 117
   106. Indusium fugaceous or lacking 107
   106. Indusium present, persistent, obvious 110
107. Very long needle-like but septate pale brown hairs on all parts of leaves . . . 27. **Lastreopsis**
107. Hairs not septate, or if septate, then only on upper side and not on all parts of leaves . . . 108
   108. Veins simple, rarely forked after leaving the midrib of ultimate lobes, 26. **Thelypteris**
   108. Veins forking in groups: the abaxial basal vein of each group comes from the costa of the pinna some distance below the midrib of the group (catadromous) . . 109
109. Pinnae deeply pinnatifid, a tooth in each sinus . . . . . 19. **Pteridrys**
109. Pinnae not deeply pinnatifid; no teeth in the sinuses; very brittle . . . 16. **Microchlaena**
   110. Margins prickly serrate; segments sharply auricled on the adiaxal side of the base . . 111
   110. Margins not prickly serrate; segments not sharply auricled on adaxial side of base, 112
111. Leaves decompound, rhizome creeping, leaves distant, not gemmiferous at or near apex; anadromous arrangement of lowest pinnules of I, II, III orders, and of basal vein of ultimate pinnules . . . . . 13. **Rumorha**
111. Leaves pinnate to bipinnate, lanceolate to oblong; rhizome oblique or erect, leaves caespitose; often gemmiferous at or near apex . . . . . 14. **Polystichum**
   112. Prominent deltoid, acute, callous tooth at each sinus between the segments of the pinnae as in *Bolbitis*; habit of *Pteris quadriaurita* . . 19. **Pteridrys**
   112. No callous tooth at the sinus 113
113. Sori on abaxial branch only of forking vein; habit of Tectaria 20 **Ctenitopsis**
113. Sori on unbranching lateral veins . . 114
   114. Multicellular, articulated, crisped, brown hairs on costa, costules, and midribs intermixed with clathrate scales with clear lumina in cells; dry leaves dry-brown or red-brown . . . . . 18. **Ctenitis**
   114. No such articulated, crisped, brown hairs; cells of scales not with clear lumina; dry leaves usually pale green (except *D. sparsa* and *Hypodematium crenata*) . . 115
115. Base of petiole swollen, covered with imbricating, bright, rufo-brown scales, no scales above base; blade densely pilose on both surfaces . . . . . 28. **Hypodematium**
115. Base of petiole not swollen, scales not limited to base, or if so, meager 116
   116. Indusium large, persistent, thick, round-reniform; rhizome erect or sometimes oblique, leaves caespitose; bases of costa and costules, and midribs decidedly decurrent; costa and costules deeply canaliculated above, with broken flexuous edges; stipe usually scaly; catadromous arrangement of lowest pinnules, 12. **Dryopteris**
   116. Indusium lacking, or small and reniform; rhizome creeping, leaves distant; costa, costules, and midribs not decurrent; grooved above, but not broken into by the lateral branches; stipe scaly only near base . . . . . 26. **Thelypteris**
117. Leaves pinnate or bipinnatifid with coadunate-pinnatifid apex; stellate or forked unicellular hairs absent; as a rule indusiate . . . . . 29. **Cyclosorus**
117. Leaves simple or imparipinnate, with the *mature* apical pinna usually being similar to the laterals; stellate or forked unicellular hairs sometimes present on rhizome scales and rachis 118
   118. Base of leaflets cordate; leaves often proliferous, scandent, and of indefinite growth; short stalked stellate or forked unicellular hairs present on rhizome scales and lower part of young rachis . . . . . 30. **Goniopteris**
   118. Base of leaflets wedge-shaped or decurrent; leaves not proliferous or of indefinite growth; stellate or forked unicellular hairs absent; indusia none or if present generally small, thin, often hirsute and as a rule fugaceous . . . . . 31. **Abacopteris**

AN ENUMERATION OF THE FERNS OF BURMA AND THEIR DISTRIBUTION[2]

OPHIOGLOSSACEAE

1. **Ophioglossum** L.

O. pedunculosum Desv. Mingaladon—L. P. Khanna. First record for Burma.

O. pendulum L. Tavoy, Hondraw River—Parish.

2. **Botrychium** Swartz

B. lunaria (L.) Sw. Adung Valley, Burma-Tibet frontier, 12,000 ft.—Ward 9986. First record for Burma.

B. lanuginosum Wall. Loimwe, Kengung State—520; Taunggyi—Maymyo Herb. 576.

3. **Helminthostachys** Kaulfuss

H. zeylanica (L.) Hk. Tenasserim—Parish; Kamorta—Kurz; Katha Distt.—Maymyo Herb 73.

ANGIOPTERIDACEAE

4. **Angiopteris** Hoffm.

A. caudatiformis Hieron. Mogok—108; Kengtung Territory—Rock 2323.

A. crassipes Wall. Thandaung--6785. First record for Burma

A. griffithsiana de Vriese. Mergui—Ind. Fil.

A. helferiana de Vriese. Taungwine, Moulmein—6865; Pyinmana—7134 First record for Burma.

OSMUNDACEAE

5. **Osmunda** L.

O. javanica Bl. In bed of streams from Mt. Nwalabo, Tavoy—Parish; Bantai, Kengtund State—9260.

O. cinnamomea L. Loimwe, Kengtung State—9104 First record for Burma.

O. japonica Thunbg. Sin Lum Kaba, Bhamo Distt.—385; Haka, Boinu River Valley, Chin Hills—7476 First records for Burma.

SCHIZAEACEAE

6. **Schizaea** Smith

S. malaccana Baker. Burma—Ind. Fil.

7. **Lygodium** Sw.

L. scandens (L.) Sw. Taungwine, Moulmein—6848; Namkham, N. S. S.—45, 219; Stilwell Rd.—Young.

L. polystachyum Wall. Madremacan, Mergui—Parish; Muang Len, Kengtung State—Rock 2017.

L. salicifolium Presl. Namkham, N. S. S.—230, 233, 239, 44; Kengtung—9180; Manhsum, Manglon State—9756; Mogok—115, 116, 117. First records for Burma.

L. flexuosum (L.) Sw. Mingaladon 615; Rangoon—43, 161, 168, 181, 467, 6583; Syriam—466; Moulmein—570, 576, 6846; Myawaddi to Kawkereik Hills, Lower Burma—Rock 678; Kengtung State—Rock 1975.

L. japonicum (Thbg.) SW. Namkham, N. S. S.—226, 231, 232, 234; N'Bapa—257, 258; Loimwe, Kengtung State—517; Mong Pawk, Kengtung State—9827; Kalaw—46; Mt. Popa—566; Taungwine, Moulmein—6846; Stilwell Rd.—Young 7.

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[2]The nomenclature used in that of Christensen's Third Supplement to his Index Filicum (1936) unless otherwise stated under the individual genera. When the relationship of species is evident, this is indicated by their order in the enumeration; when the relationship is not evident, species are arranged alphabetically.

GLEICHENIACEAE

8. **Dicranopteris** Bernhardi
(Ching 1940c)

D. linearis (Burm.) Underw. Amherst and Mergui—Parish; Kalaw—14; Thandaung—14B; Namkham—14A; Mogok—3005; Sin Lum Kaba—335; Loimwe—533, 9129; Stilwell Rd.—Young 25.

D. splendida (Hand. & Mazz.) Ching. Thandaung—50; Loimwe—533. First records for Burma

9. **Hicriopteris** Presl
(Ching 1940c)

H. glauca (Thbg.) Ching. Nattaung Mt.—Parish; Sin Lum Kaba—297, 322; Stilwell Rd.—Young 66.

H. laevissima (Christ) Ching. Sin Lum Kaba—283. First record for Burma

CYATHEACEAE

10. **Cyathea** Smith
(Copeland 1909, Holttum 1935)

C. brunoniana (Wall.) Cl. & Bak. Between Sadon and the Yunnan border—Rock 7464.

C. contaminans (Wall.) Copel. Kengtung State—Rock 2097, 2087; Mogok—133A.

C. decipiens (Scott) Cl. & Bak. Mogok—133. First record for Burma.

C. gigantea (Wall.) var. or sp. nov. Loimwe, Kengtung State—9123 First record for Burma.

C. glabra (Bl.) Copel. Kengtung State—Rock 2032, 2041, 2153, 2341; Mts. in Tenasserim—Parish; Taungyeghat, Pegu Distt.—328.

C. khasyana (Moore) Copel. Between Sadon and Yunnan border—Rock 7431; Khunpoye, Kungtung State—9247.

C. latebrosa (Wall.) Copel. Mergui—Maymyo Herb.

C. oldhami (Bedd.) Copel. Moulmein—Clarke & Beddome; Mooleyit—Parish.

C. spinulosa Wall. Namkham—619, 20. First record for Burma.

C. umbrosa Holttum. Taungwine, Moulmein—8854. First record for Burma.

PERENEMACEAE Presl, emend.
(Ching 1940b)

11. **Diacalpe** Blume

D. aspidioides Bl. Mooleyit, Tavoy—Beddome and Clarke; Mt Nwalabo, Tavoy—Parish; Moulmein—Clarke; Mogok—125; Namkham—252, 260; Sin Lum Kaba—305, 307; Bantai, Kengtung State—9252.

ASPIDIACEAE Presl. emend.
(Ching 1940b)

TRIBE 1. DRYOPTERIDEAE

12. **Dryopteris** Adanson, sensu propria.
(Ching 1938c)

D. scottii (Bedd.) Ching. Sin Lum Kaba—358, 376; Haka, Chin Hills—7415.

D. stenolepis (Bak.) C. Chr. Kambaiti Valley—Rock 7507; Namkham—321.

D. atrata (Wall.) Ching. Kengtung State—Rock 2207; Kengtung—9236; Sin Lum Kaba—330; Falam, Chin Hills—7254; Haka, Chin Hills—7505, 7370.

D. paleacea (Sw.) C. Chr. Between Sadon and the Yunnan border—Rock 7506; Sin Lum Kaba—334, 391; Haka, Chin Hills—7510.

D. odontoloma (Moore) C. Chr. Sin Lum Kaba—333; Taungteik, Chin Hills—7247; Haka, Chin Hills—7708; Stilwell Rd.—Young. First records for Burma.

D. chrysocoma (Christ) C. Chr. Mt. Popa—545, 6614. First records for Burma.

D. cochleata (Don) C. Chr. Kengtung State—Rock 2265, 2245; Kengtung—9173, 9174, 9174A; Taunggyi—178; Mt. Popa—547; Kalemyo, Chin Hills—7220, 604.

D. labordii (Christ) C. Chr. Namkham—229. First record for Burma.

D. marginata (Wall.) Christ. Between Sadon and the Yunnan border—Rock 7504.

D. angustifrons (Moore) C. Ktze. Burma—Mebold.

Dryopteris sparsa (Ham.) Ktze. Tenasserim Distt.—Parish; Sadon to Yunnan border—Rock 7503; Sin Lum Kaba—277, 345, 411; Mogok—328; Namkham—12, 311; Pangwai, Kengtung State—9239, 9103, 9131; Stilwell Rd.—Young 51.

D. hendersoni (Bedd.) C. Chr. Namkham—240, 250. First records for Burma.

13. **Rumohra** Raddi
(Ching 1934b)

R. assamica (Kuhn) Ching. Stilwell Rd., Burma-Assam border—Young. First record for Burma.

R. aristata (Forst.) Ching. Burma—Parish; Stilwell Rd.—Young 84.

R. speciosa (Don) Ching. Namkham—255, 301; Pangwai, Kengtung State—9201. First records for Burma.

R. simulans Ching. Namkham—317; Nawng Heng, Burma-Yunnan border 292. First records for Burma.

R. henryi (Christ) Ching. Kengtung State—Rock 2233; Sin Lum Kaba—340.

R. diffracta (Bak.) Ching. Loimwe, Kengtung State—9120; Nam Tamai Valley, 4000 ft.—Ward 9159. First records for Burma.

14. **Polystichum** Roth.

P. thompsoni (Hk. f.) Bedd. Adung River, Burma-Tibet frontier—Ward 9186. First record from Burma.

P. deltodon (Bak.) Diels. Maymyo—7. First record for Burma.

P. obliquum (Don) Moore. Goteik Gorge—212. First record for Burma.

P. auriculatum (L.) Presl. Stilwell Rd.—Young

P. neolobatum Nakai (?). Taungteik, Chin Hills—7541. First record for Burma.

P. attenuatum Ching. Namkham—30, 253; Mogok—104; Sin Lum Kaba—332. First records for Burma.

P. chunii Ching. Namkham—259, 303. First records for Burma.

P. pseudotsus-simense Ching. Burma-Ind. Fil. III.

P. biaristatum (Bl.) Moore. Kengtung State—Rock 2116, 2117, 2309; Sin Lum Kaba—403.

P. biaristatum form. Sin Lum Kaba—359.

P. setiferum (Forsk.) Moore. Mogok—128, 145; Chin Hills; Falam—7276; Yetagone—7542; Taungteik—7299.

P. setiferum (Forsk.) Moore var. or sp. Falam—7280.

P. setiferum (Forsk.) Moore var. or sp. Falam—7302, 7303, 7372; Haka—7509.

P. yunnanense Christ. Sin Lum Kaba—358?; Mogok—129?; Haka—7508, 7782, 7784; between Sadon and Yunnan border—Rock 7521.

P. punctiferum C. Chr. Between Sadon and Yinan border—Rock 7522.

15. **Cyclopeltis** J. Smith

C. presliana (J. Sm.) Berkeley. Burma—Ind. Fil.

16. **Microchlaena** Ching
(Ching 1938b)

M. yunnanensis (Christ) Ching. Kengtung State—Rock 2212; Pangwai, Kengtung State—9195, 9243; N'Bapa—270.

17. **Cyrtomium** Presl

C. hookerianum (Presl) C. Chr. Sin Lum Kaba—352. First record for Burma.

TRIBE 2. ASPIDIEAE

18. **Ctenitis** C. Chr.

C. clarkei (Bak.) Ching. Between Sadon and the Yunnan border—Rock 7405.

C. rhodolepis (Cl.) Ching. Maymyo—425; Taunggyi—9822. First records for Burma.

19. **Pteridrys** C. Chr. & Ching

P. australis Ching. Valley of the Meh Len, Kengtung State—Rock 2141.

P. cnemidaria (Christ) Ching. Tenasserim Distt.—Parish; Kengtung State—Rock 2140; Taunggyi—9291.

20. **Ctenitopsis** Ching
(Ching 1938b)

C. sagenioides (Mett.) Ching. Tenasserim—Parish.

C. fuscipes (Wall.) Ching. Taungup—Lace 2936; Pyinmana—7121; Zwagabin, Moulmein Distt. —7022.

C. setulosa (Bak.) Ching. Khunpoye, Kengtung State—9259. First record for Burma.

21. **Egenolfia** Schott
(Ching 1931d)

E. appendiculata (Willd.) J. Sm. Tenasserim—Parish; Taungwine, Moulmein—6849; Pyinmana—7120; Stilwell Rd.—Young.

E. sinensis (Bak.) Maxon. Moulmein (?)—6621, 6657, Pyinmana—7130; Loimwe, Kengtung—9140. First records for Burma.

E. bipinnatifida J. Sm. Tenasserim—Parish; Moulmein—6751.

E. helferiana (Kunze) C. Chr. Oktada, Martaban Hills, Kalama Range—Rock 759; Kyain, Amherst Distt.—6867.

E. helferiana var. incisa. Lower Burma—Rock 759.

E. nodiflora (Bory) Fée. Mawlaik, Upper Chindwin Distt —Rock 823; type from Pegu.

22. **Tectaria** Cav.
(Ching 1931f)

T. polymorpha (Wall.) Copel. Moulmein—Parish 145; Thandaung—6750; Goteik Gorge—209; Namkham—9,236; N'Bapa—272; Kengtung—9167; Rock 1954, 2084, 2090.

T. heterosora (Bak.) Ching. Stilwell Rd.—Young.

T. tenerifrons (Hk.) Ching. Moulmein—Parish 92 (type).

T. chattagramica (Cl.) Ching. Sandwut—Lace 4799, 5178.

T. vasta (Bl.) Copel. Kengtung State—Rock 1938, 1957, 2132, 2139.

T. subtriphylla (Hk. & Arn.) Copel. Burma. Parish; Htam Sang Caves, Hopong State—8094.

T. subtriphylla (Hk. & Arn.) Copel. var. appr. T. Rockii. Zwegabin, Moulmein—7043; Goteik Gorge—208.

T. rockii C. Chr. Goteik Gorge—Lace 4857 (1909); 208A, 9525; Takaw Ferry—9288, Sampu, Namkhok State—8345; Kanpetlet, Chin Hills—8570.

T. irregularis (Presl) Copel. Tenasserin—Parish.

T. irregularis (Presl) Copel. var. difformis Bl. Mergui—Maymyo Herb. Kyaukthanba, Pyinmana—7121.

T. subpedata(Harr.) Ching. Namkham—28.

T. decurrens (Presl) Copel. Goteik Gorge—Lace 4993 (1909).

T. variolosa (Wall.) C. Chr. Tavoy—7977, Moulmein—567, 6844; Pegu-Clarke; Syriam—462, Mt. Popa—6626 (?).

T. ebenina (C. Chr.) Ching. Kalemyo—7219; Tiddim, Chin Hills—623 (?).

T. coadunata (Wall.) Ching. Moulmein—Parish, Maymyo Herb. 561.

T. multicaudata (Wall.) Ching. Moulmein and Mergui—Beddome; Chappedaung—Wallich.

23. **Bolbitis** Schott

B. contaminans (Wall.) Ching. Burma—Beddome.

B. deltigera (Wall.) C. Chr. Zwegabin, Moulmein—7029; Yetagone, Chin Hills—7766.

B. heteroclita (Presl) Ching. Tenasserim Distt.—Parish.

B. scalpturatus (Fee) Ching. Tenasserim Distt.—Parish.

B. undulata (Wall.) Ching. Martaban—Parish (1827); Zwegabin, Moulmein—7014; Thandaung (?)—6711.

24. **Stenochlaena** J. Smith

S. palustris (Burm.) Bedd. Tenasserim—Parish; Moulmeingyun, Henzada—6903; Rangoon—6537; Thandaung—58.

S. sorbifolia (L.) J. Sm. Tenasserim—Beddome; Packchan—Parish.

25. **Lomagramma** J. Smith
(Holttum 1937b)

L. matthewii (Ching) Holttum. Salween River, Road to Kengtung—9289. First record for Burma

THELYPTERIDACEAE Ching
(Ching 1940b)

TRIBE 1. THELYPTERIDEAE

26. **Thelypteris** Schmidel
(Ching 1936c)

T. aurita (Hk.) Ching. Upper Burma—G. Forrest.
T. oppositipinna (v.A v.R.) Ching Sin Lum Kaba—357. First record for Burma.
T. brunnea (Wall.) Ching Namkham—274, 312. First records for Burma
T. chlamydophora (Rosenst.) Ching. Burma—Ind. Fil. III.
T. ciliata (Wall.) Ching. Kengtung State—Rock 2185, 2206; Valley of the Nam Tamai, Burma-Tibet frontier—Ward 9117; Stilwell Rd.—Young 7; Thandaung —6782.
T. erubescens (Wall.) Ching. Falam, Chin Hills—7270, 7271; Haka, Chin Hills 7390, 7413. First records for Burma
T. tuberculifera (C. Chr.) Ching. Kalaw—13A; Taunggyi—176; Loimwe, Kengtung State—9106; Falam, Chin Hills—7239; Haka, Chin Hills—7611. First records for Burma.
T. xylodes (Kze.) Ching. Kengtung State—Rock 2234; Loimwe—523 (?); Mogok—154; Sin Lum Kaba—276; Falam, Chin Hills—7250.
T. falcatoloba (Hk.) Ching Kengtung State -Rock 2082; Kengtung—9182, 9225, Maymyo—8; Mogok—143
T. ochthodes (Kze.) Ching. Thandaung—6778; Kalaw—13; Loimwe, Kengtung—9106A; Mogok—148; Haka, Chin Hills—7573. First records for Burma.
T. duclouxii (Christ) Ching. Burma—Maymyo Herb. 566. First records for Burma.
T. glanduligera (Kze.) Ching. Sin Lum Kaba—459 (probably). First record for Burma.
T. flaccida (Bl.) Ching. Sin Lum Kaba—379. First record for Burma.
T. uliginosa (Kze.) Ching. Anisakan—427; Mt. Popa—6619. First records for Burma.
T. ornata (Wall.) Ching Burma—Parish; East of Bhamo—Rock 7842.

27. **Lastreopsis** Ching

L. parishii (Hk.) O. Ktze. Moulmein—Parish.

28. **Hypodematium** Kunze
(Ching 1935b)

H. crenatum (Forsk.) Kuhn. Anisakan—422, 428; Mt. Popa—548, 6620; Yetagone, Chin Hills—7333. First records for Burma.

TRIBE 2. GONIOPTERIDEAE

29. **Cyclosorus** Link
(Ching 1938a)

C. crinipes (Hk.) Ching. Kengtung State—Rock 2089; Yanka, Kengtung—9234; Mong Nai, S. S. S.—7852; Takaw Ferry—9287; Sin Lum Kaba—347; Mogok—151; Kyaukthanba, Pyinmana—7125.
C. extensus (Bl.) Ching Tenasserim—Parish.
C. multijugus (Bak.) F. G. D. Falam, Chin Hills—7289. First record for Burma.
C. interruptus (Willd.) Ching. Tenasserim Distt.—Parish; Kyauktalon, Moulmein Distt.—6837; 6842; Mt. Popa—6604; Goteik Gorge—204.
C. gongylodes (Schkuhr.) Link. Kyain, Moulmein—6859; Mingaladon—603; Inle Lake, S. S. S.—187, 7880; Kengtung—9190. First records from Burma.
C. molliusculus (Wall.) Ching. Kengtung State—Rock 3187, 2189.
C. parasiticus (L.) Farwell. Thandaung—66; Namkham—300; Pangwai, Kengtung State—9203. First records for Burma.

C. subpubescens (Bl.) Ching. Kyauktalon, Moulmein—6837A, 6840, 6841, Kyain, Moulmein—6858; Mt. Popa—6627A; Rangoon—188, 6627; Maymyo—415, 423; Goteik Gorge—210; Namkham—222; Falam, Chin Hills—7248; Pyinmana—7109

C. burmanicus Ching. Kengtung State—Rock 2247.

C. meeboldi (Rosenst.) Ching. Tenasserim—Meebold 2152 (type).

C. truncatus (Poir.) Farwell. Kengtung State—Rock 1966; Yanka, Kengtung State—9226 sens lat.

C. hirtisorus (C. Chr.) Ching. Kengtung State—Rock 2208 (type), 2235, Loimwe, Kengtung—514, Mogok—55A (?).

C. subelatus (Bak.) Ching. Kengtung State—Rock 2113, Kengtung—9185, 9185A; Mogok—152; Namkham—323, 324

30 **Goniopteris** Presl
(Ching 1938a)

G. prolifera (Retz) Presl. Mergui—Hope; Kengtung State—Rock 2115; N'Bapa—288; Kalemyo—7202; Tiddim, Chin Hills—601

31. **Abacopteris** Fee emend
(Ching 1938a)

A. triphylla (Sw.) Ching. Tenasserim—Parish; Kyain, Amherst Distt.—6866; Stilwell Rd.—Young 39.

A. triphylla var. parishii (Bedd.) Ching. Tenasserim—Beddome.

A. rubra Ching. Thandaung—54, 6787; Loimwe, Kengtung—532, 9122.

A. rubra var. hirsuta Ching. Kengtung State—Rock 2136; Maymyo 41; Stilwell Rd.—Young 33

A. presliana Ching. Namkham—246; Yetagone, Ching Hills—7309.

A. multilineatum (Wall.) Ching. Moulmein—Parish; Kyain, Amherst Distt.—6856, Sin Lum Kaba—339; Namkham—39, 237, N'Bapa—304, Kengtung State—Rock 1936, 1938, 2142

A. penangiana (Hk.) Ching. Maymyo—412, 421A, 421 (?) First records from Burma.

ASPLENIACEAE Presl
(Ching 1940b)

TRIBE I ATHYRIEAE

32. **Athyrium** Roth.

A. acrostichoides (Sw.) Diels. Sin Lum Kaba—266. First record for Burma.

A. atkinsoni Bedd. Sin Lum Kaba—354. First record for Burma.

A. australe (R. Br.) Presl. Burma—Beddome.

A. boryanum Tagawa (= Dryoathyrium Ching). Toungoo—Maymyo Herb. 565.

A. brevisorum (Wall.) Moore. Taungdong Mts. near Ava—Wallich.

A. dissitifolium (Bak.) C. Chr. Kengtung State—Rock 2666, Rock 2691; Loimwe—511, 512, 9208; Taunggyi—179, 9390; Kalaw—23; Maymyo—418 (?); Falam, Chin Hills—7351; Haka, Chin Hills—7570.

A. dissitifolium f. subbipinnata. Tiddim Chin Hills—600; Haka—7694.

A. drepenopterum (Kze.) R. Br. Between Sadon and Yunnan border—Rock 4776; Mogok—112, 144.

A. drepenopterum var. funebre Christ. Between Sadon and Yunnan border—Rock 7477.

A. falcatum Bedd. Mt. Popa—541. First record for Burma.

A. macrocarpum (Bl.) Bedd. Near Kambaiti—Rock 7484.

A. nigripes (Bl.) Moore. Between Sadon and Yunnan border—Rock 7519.

A. niponicum (Mett.) Hance. Taunggyi—177, 177A. First record for Burma.

A. procerum (Wall.) Milde. Mogok—131; N'Bapa—280, 286; Haka, Mossy Forest—7511. First records for Burma.

A. setiferum C. Chr. Between Sadon and Yunnan border—Rock 7518, Rock 7520.

A. spectabile (Wall.) Presl. Goteik Gorge—211; Takaw, Kengtung State—9286. First records for Burma.

A. strigillosum Moore. Between Sadon and Yunnan border—Rock 7420 (?).

33. **Cystopteris** Bernhardi

C. tenuisecta (Bl.) Mett. Moulmein Mts.—Bedd.; Mooleyit, Tavoy—Parish.

34. **Diplazium** Swartz

D. bantamense Bl. Tenasserim—Parish; Stilwell Rd.—Young.

D. dilatatum Bl. f. ***diversifolium*** (Wall.) Kengtung State—Rock 2134.

D. dilatatum Bl. f. ***latifolium*** (Don). Kengtung State—Rock 2036, Rock 2184; between Sadon and Yunnan border—Rock 7443; Loinwe—9141A; Mogok—102, 149, 342.

D. esculentum (Retz) Sw. Kengtung State—Rock 2114; Teeyang, Tenasserim Distt.—Parish; Tavoy—8015; Kyain, Amherst Distt.—6857; Kalemyo—7228.

D. japonicum (Thbg.) Bedd. Stilwell Rd.—Young 78.

D. lanceum (Thbg.) Presl. Stilwell Rd.—Young 7. First record for Burma.

D. leptophyllum (Bak.) Christ. Kengtung—9172A; Haka, Chin Hills—7572. First records for Burma.

D. lobbianum (Hk.) Moore. Kengtung State—Rock 1937.

D. megaphyllum (Bak.) Christ. Salween River at Kengtung Road—9290. First record for Burma.

D. opacum (Don) Christ. Loimwe, Kengtung State—9141. First record for Burma.

D. pallidum (Bl.) Moore. Tenasserim—Parish.

D. peterseni Kze. Thandaung (?) —6736. First record for Burma.

D. polypodioides Bl. Between Sadon and Yunnan border—Rock 7434; Takaw, Kengtung State—9294; Haka, Chin Hills—7482.

D. siamense C. Chr. ***f. acuminata***. Loimwe, Kengtung—506. First record for Burma.

D. sikkimense (Cl.) C. Chr. Kengtung State—Rock 2183.

D. silvaticum (Bory) Sw. Chappedong Hill, Burma—Clarke.

D. tomentosum Bl. Tenasserin—Parish.

D. viridissimum Christ. Kengtung State—Rock 2131.

35. **Diplaziopsis** C. Chr.

D javanica (Bl.) C. Chr. Stilwell Rd.—Young 29. First record for Burma.

Tribe 2. Asplenieae

36. **Phyllitis** Hill

P. delavayi (Franch) C. Chr. Upper Burma—Ind. Fil.

37. **Thamnopteris** Presl.

T. nidum L. Tenasserim Distt.—Parish; beyond Sadon near Yunnan border—Rock 7467; Loije, Bhamo Distt.—410; Yanka, Kengtung State—9229.

T. phyllitidis (Don) Presl. Kengtung State—Rock 2181.

T. grevellei (Wall.) Moore. Tavoy Island—Parish.

38. **Asplenium** L.

A. ensiforme Wall. Ta-ok—Parish, Tennaserim—Hope; Moulmein—Clarke; Nattaung, Karrenni—9457; Ashe-myin-Anauk-myin, Lawk Sawk State—8703, 8717; Sampu, Namkhok State—8359; Mt. Victoria, Chin Hills; 8595, 8598; Mogok, Taungme—110; Sin Lum Kaba—402; N'Bapa—209; Pangyang, Manglun State—8071; Adung Valley, Burma-Tibet frontier—Ward 9334.

A. griffithianum Hk. Mergui and Tavoy—Beddome; Stilwell Rd.—Young 64; Burma-Tibet frontier, Nam Tamai Valley—Ward 9165.

A. amboinense Willd. Mergui and Tavoy—Parish.

A. normale Don. Ta-ok—Parish; Loimwe, Kengtung State—9121; Stilwell Rd.—Young 82.

A. normale var. ***minus***—Kambaiti—Rock 7508.

A. longissimum Bl. Moulmein southwards—Parish.

A. wightianum Wall. Burma—Beddome.

A. tenerum Forst. Tenasserim Distt.—Parish.

A. pellucidum Lam. Madremacan Is., Nergui—Parish; Moulmein—Bedd.

A. cheilosorum Kunze. Zwakabin—Parish; Nattaung, Karrenni—9479, 9418; between Sadon and Yunnan border—Rock 7425; Stilwell Rd.—Young 89.

A. unilaterale Lam. Zwegabin, Moulmein—7024; Nattaung, Karrenni—9477; Mt. Popa—6602.

A. unilaterale var. *rahaoense* (Yabe) Hay. Between Pang Ma Ki Hat and the Siamese border—Rock 1947; Stilwell Rd.—Young 12.

A. unilaterale var. *delicatulum* Par. Mergui—Parish, Ta-ok—Parish.

A. unilaterale var. *udum* Atk. Htam Sang Caves, Hopong State—8269; Sampu, Namkhok State—8291; Mt. Victoria—8456, 8498, 8568; Haka—7574; Stilwell Rd.—Young 68.

A. adiantoides (L.) C. Chr. Moulmein southwards—Clarke; Hopong, Hopong State—8264 (?), 8087 (?).

A. macrophyllum Sw. Stilwell Rd.—Young 16. First record for Burma.

A. urophyllum Wall. Henzada—6900. First record for Burma.

A. exiguum Bedd. Kalaw—15; Taunggyi—8093, 9391. First records for Burma.

A. rockii C. Chr. Near N'Bapa ford, Burma-Yunnan border 290A. First record for Burma.

A. laciniatum Don. Kalaw—16; between Sadon and Yunnan border—Rock 7422

A. planicaule Wall. Between Sadon and Yunnan border—Rock 7417; Mogok—103, 120; Taunggyi—9313; Thandaung 6714A; Haka, Chin Hills—7366, 7556, 7579.

A. crinicaule Hance. Mt. Nwalabo, Tavoy Distt. (?)—8245; Sin Lum Kaba—398; Stilwell Rd.—Young. First records for Burma

A. praemorsum Sw. Thandaung—6714. First record for Burma.

A. nitidum Sw. Tenasserim Distt.—Parish.

A. cuneatum Lam. Stilwell Rd.—Young. First record for Burma.

A. bullatum Wall. Adung Valley, Burma-Tibet frontier—Ward 9185.

A. tenuifolium Don. Kalamataung, Martaban—Parish; Bernardmyo, Mogok—123; Mt. Victoria, Chin Hills—8515; Ashe-myin Anauk-myin, Lawk Sawk State—8709, Sampu, Namkhok State—8332; Pangwai, Kengtung State—9215, Pangyang, Manglun State—8073.

A schilleifolium (Lam) C. Chr. Maymyo Herb. 588.

39. **Ceterach** Garsault

C paucivenosa Ching. Adung Valley, Burma-Tibet frontier—Ward 9230. First record for Burma.

OLEANDRACEAE Ching
(Ching 1940b)

40. **Oleandra** Cav.

O. cumingii J. Sm. Taungwine Range, Moulmein—Parish; Madremacan, Mergui—Parish.

O. musifolia (Bl.) Presl. Thandaung—60. First record for Burma.

O. neriiformis Cav. Dauna-taung east of Moulmein—Parish.

O. undulata (Willd.) Ching. Moulmein—Baker; Kengtung State—Rock 2026.

O. wallichii (Hk.) Presl. Burma—Beddome.

BLECHNACEAE Ching
(Ching 1940b)

TRIBE 1. BLECHNEAE

41. **Blechnum** L.

B. orientale L. Moulmein—Parish; Taungwine, Moulmein—6350, Kyain, Amherst Distt.—6855; Taung Thonta, Tavoy—8011; Rangoon—8131; Thandaung—59; Mogok—620; Namkham—4, 18, 19, 223; Pangyang, Manglum State—8084.

TRIBE 2. WOODWARDIEAE

42. **Woodwardia** Smith
(Ching 1931a)

W. japonica (L.) J. E. Smith. Kengtung State—Rock 2006; Loimwe, Kengtung State—9102.

W. unigemmata Nakai. Adung Valley, Burma-Tibet frontier—Ward 9309. First record for Burma.

Tribe 3. Braineae

43. **Brainea** J. Sm.

B. insignis (HK.) J. Sm. Mooleyit, Tavoy—Parish; Yunzalin Mts.—Parish; Mogok—139; east of Pangyang, Manglun State—very common, trunks 3 ft. high; Loimwe—9235; Kengtung State—Rock 2028.

PLATYCERIACEAE Ching
(Ching 1940b)

44. **Platycerium** Desv.

P. coronarium (Konig) Desv. Mergui and Islands—Parish.

P. wallichii Hk Tenasserim—Beddome; Taungwine, Moulmein—Parish; Moulmein—31, Pyinmana—500; Thandaung—8397; Anisakan, Maymyo—419; Kalemyo—7223; Bhamo.

GRAMMITACEAE Presl emend
(Ching 1940b)

45. **Ctenopteris** Blume

C. khasyana (Hk.) Dickason. Nam Tamai Valley, Upper Burma—Ward 9146. First record for Burma.

C. subfalcata (Bl.) Dickason. Between Sadon and Yunnan border—Rock 7400, Nattaung, Karenni—9460; Haka, mossy forest—7578

POLYPODIACEAE Presl (sensu propria)
(Ching 1940b)

Subfamily 1. Polypodioideae

45. **Polypodium** L.
(Ching 1933d)

P. manmeiense Christ. Taunggyi—471, 8112, 8115, 9050; Loimwe, Kengtung State—534; Pangyang, Manglun State—8059; Nattaung, Karenni—9458. First records for Burma.

P. microrhizoma Clarke. Maymyo Herb 25678.

P. nipponicum Mett. Burma—Ind. Fil.

P. amoenum Wall. Between Sadon and Yunnan border—Rock 7455; Pangyang, Manglun State—8058; Nattaung, Karenni—9471; Mogok—137; Sin Lum Kaba—375; Stilwell Rd.—Young 83.

P. argutum Wall. Between Sadon and Yunnan border—Book 7500.

P. pseudoconnatum Copel. Kyaukme Taung, Tavoy Distt.—8009.

P. subauriculatum Bl. Tenasserim Distt.—Parish.

P. beddomei Bak. Waytamurgay, S. S. S.—Parish.

Subfamily 2. Pleopeltioideae

47. **Neocheiropteris** Christ
(Ching 1933b)

N. ensata (Thbg.) Ching. Stilwell Rd.—Young 11. First record for Burma.

N. phyllomanes (Christ) Ching. Htam Sang Caves, Hopong State—8268; Namkham—40; Kanpetlet, Chin Hills—8429; Yetagone, Chin Hills—7752. First records from Burma.

N. lancifolia (Alston) Dickason. Nam Tamai, Upper Burma—Ward 9172 (type).

48. **Lepisorus** (J. Sm.)Ching
(Ching 1933b)

L. contortus (Christ) Ching. Sin Lum Kaba—633; Kalaw—629. First records for Burma.

L. excavatus (Bory) Ching var. *scolopendrinum* (Ham.) Ching. Maymyo Herb.—1774; Sin Lum Kaba—365 probably. First records for Burma.

L. macrosphaerus (Bak.) Ching. Kalaw—631; Sin Lum Kaba—367, 371, 377. First records from Burma.

L. macrosphaerus var. *asterolepis* (Bak.) Ching. Taunggyi—8378, 9047; Sampu, Namkhok State—8363; Molahein Mt., Lawk Sawk State—8744; Mt. Popa—563; Mt. Victoria—8486,

8590, Falam, Chin Hills—7244; Haka, Chin Hills—7399, 7418, 7598. First records for Burma.

L. obscure-venulosus (Hav.) Ching. Kalaw—630, 628 (near). First records for Burma.

L. oligolepidus (Bak.) Ching. Between Sadon and Yunnan border—Rock 7494; Thandaung—6720.

L. oosphaerus (C. Chr.) Ching. Kalaw—9592; Taunggyi—8125, 8786, 9048, Loimwe, Kengtung State—502. First records for Burma.

L. pseudonudus Ching. Between Sadon and Yunnan border—Rock 7498; Thandaung—6786.

L. sinensis (Christ) Ching. Between Sadon and Yunnan border—Rock 7488, Lin Lum Kaba—364.

L. sordidus (C. Chr.) Ching *forma rostrata* (C. Chr.) Ching. Between Sadon and Yunnan border—Rock 7509.

L. subconfluens Ching. Namkham—302A (?). First record for Burma.

L. sublinearis (Bak.) Ching. Between Sadon and Yunnan border—Rock 7424; Loi Maing, Sampu, Namkhok State—8364, Haka, Chin Hills—7558, 7576.

L. sublinearis var. Kalaw—4. First record for Burma.

L. thunbergianus (Klf.) Ching. Between Sadon and Yunnan border—Rock 7421, Sin Lum Kaba—633; Mogok-Bernardmyo Rd.—172; Namkham—632; Mt. Popa—560; Thandaung—51

49. **Hymenolepis** Kaulfuss
(Christensen 1929)

H. henryi Hieron. Stilwell Rd.—Young. First record for Burma.

50. **Lemmaphyllum** Presl
(Christensen 1929)
(Ching 1933b)

L. subrostratum (C. Chr.) Ching. Dauna Taung, east of Moulmein—Parish, Sampu, Namkhok State—8353; between Sadon and Yunnan border—Rock 7493, Falam, Chin Hills—7273; Stilwell Rd.—Young 9.

TRIBE 2. PHYMATODEAE

51. **Phymatodes** Presl
(Ching 1933d)

P. griffithiana (Hk.) Ching. Between Sadon and Yunnan border—Rock 7528; Yatagone, Chin Hills—7350.

P. rhyncophylla (Hk.) Ching. Dauna Taung. Parish; Mooleyit, Tenasserim—Beddome, between Sadon and Yunnan border—Rock 7513; Loije—Sin Lum Kaba Rd.—390; Nattaung, Karenni—9453.

P. crenato-pinnata (Cl.) Ching. Kalaw—9588; Taunggyi—181, 8771; Loimwe, Kengtung State—526. First records for Burma.

P. trisecta (Bak.) Ching. Maymyo Herb.

P. oxyloba (Wall.) Presl. Daung Taung—Parish; Thandaung—53; Nattaung, Karenni—9452; Molahein Mt., Lawksawk State—8760; Pangyang, Manglun State—8066; Loimwe, Kengtung State—525; Tiddim, Chin Hills—626.

P. sp. nov. Mt. Popa—538. First record for Burma.

P. lucida (Roxb.) Ching. Kalaw—27, 405; Sin Lum Kaba—341. First records for Burma.

52. **Selliguea** Bory emend.
(Ching 1933c)

S. fée Bory. Tenasserim and Mergui—Parish.

53. **Microsorium** Link
(Ching 1933c)

M. normale (Don) Ching. Mooleyit, Tenasserim—Beddome; Mergui—Parish; between Sadon and Yunnan border—Rock 7510; Sampu, Namkhok State—8338; Ashe-myin Anaukmyin, Lawksawk State—8702.

M. hymenodes (Kze.) Ching. Yetagone, Chin Hills—7754; Stilwell Rd.—Young. First records from Burma.

M. superficiale (Bl.) Ching. Between Sadon and Yunnan border—Rock 7497; Sin Lum Kaba—400; Pangwai, Kengtung State—9202; Taungteik, Chin Hills—7298.

M. punctatum (L.) Copel. Kengtung State—Rock 2138; Bhamo—412; Goteik Gorge—207; Hrawng Vung, Haka, Chin Hills—7637; Moulmeingyun—6913; Moulmein—6852; Tavoy—7986.

M zippelii (Bl.) Ching. Sin Lum Kaba—408. First record for Burma.

M. membranaceum (Don) Ching. Tenasserim Distt.—Parish; between Sudan and Yunnan border—Rock 7478; Thandaung—52. Taunggyi—8118, 9029.

M. hancockii (Bak.) Ching. Tenasserim—Parish; Kengtung State—Rock 2135; Loimwe, Kengtung State—9143.

M. zosteriforme (Wall.) Ching. Mooleyit, Tenasserim—Parish.

M. pteropus (Bl.) Ching. Kyain, Amherst Distt.—6866A; Stilwell Rd.—Young 32.

54. Colysis Presl
(Ching 1933c)

C. hemionitidea (Wall.) Presl. Tenasserim Distt.—Parish.

C. pedunculata (Hk. & Grev.) Ching. Stilwell Rd.—Young. First record for Burma.

C. henryi (Bak.) Ching. Stilwell Rd.—Young 67. First record for Burma.

C. latiloba Ching. Sin Lum Kaba—349. First record for Burma.

C. flexiloba (Christ) Ching var. *undulato-repanda* (C. Chr.) Ching. Sin Lum Kaba—407. First record from Burma.

C. elliptica (Thbg.) Ching. Tenasserim—Parish; Stilwell Rd.—Young 69.

C. elliptica var. *pothifolia* (Don) Ching. Ashe-myin Anauk-myin, Kawksawk State—8710; Sampu, Namkhok State—8295, 8324; Loimwe, Kengtung State—9144; Namkham 319.

55. Leptochilus Kaulf.
(Ching 1933c)

L decurrens Bl. Kengtung State—Rock 2137; Goteik Gorge—214; Thandaung—6790.

L. lanceolatus Fée. Burma—Beddome.

L. axillaris (Cav.) Kaulf. Tenasserim—Parish; Pegu—Clarke.

56. Arthromeris J. Smith
(Ching 1933d)

A. tenuicauda (Hk.) Ching. Tibetan-Burmese border—Ching.

A. wallichiana (Spreng) Ching. Moulmein—Clarke; Sin Lum Kaba—Loije Rd. 42nd mile—350.

A. wardii (Cl.) Ching. Maikha-Salween—Forrest 25974.

A. lehmanni (Mett.) Ching. Dauna Taung—Parish; Upper Burma—Forrest 24922; Kalaw—9591; Taunggyi—180, 8104, 8787, 8698, 8699.

A. lehmanni var. *mairei* (Brause) Ching. Tiddim, Chin Hills—627. First record for Burma.

A. lehmanni var. *auriculata* Ching. Upper Burma—Forrest 24922.

A. himalayense (Hk.) Ching. Dauna Taung—Parish.

57. Pseudodrynaria C. Chr.

P. coronans (Wall.) C. Chr. S. E. of Moulmein—Parish; Toungoo—Parish; Tenasserim—Beddome; Yanka, Kengtung State—9222; Manhsum, Manglun State—9678; Mong Yang, Kengtung State; Stilwell Rd.—Young; between Muang Len and Muang Hpyak—Rock 2033.

58. Drynaria Bory

D. propinqua (Wall.) J. Sm. Kalaw—6A; Maymyo—420; Taunggyi—478; Pangwai, Kengtung State—7882, 9207; Mt. Popa—558; Kalemyo—7290; Stilwell Rd.—Young.

D. quercifolia (L.) J. Sm. Moulmein—578; Rangoon (very common)—163, 168, 190; Wakema—7822; Bhamo—414; Kalewa—7190.

59. **Pyrrhosia** Mirbel
(Ching 1935a)
= Cyclophorus Desv.

C. mollis (Kze.) Presl. Shan Hills—Collett; Thandaung—6745; Kalaw—625; Taunggyi—7845, 8113, 8657; Hopong—8262; Sin Lum Kaba—343; Haka, Chin Hills—7420.

C. flocculosus (Don) C. Chr. Between Sadon and Yunnan border—Rock 7462; Mogok—170; Mt. Popa—493, 503; Kalaw—L. P. Khanna.

C. penangianus (Hk.) Ching. Tenasserim—Parish.

C. stigmosus (Sw.) Desv. Tenassrim—Beddome; Tavoy—Parish.

C. beddomeanus (Gies.) C. Chr. Wetwun, near Myamyo—62; Htam Sang Gaves, Hopong State—8100, 8261. First records for Burma.

C. subfurfuraceus (Hk.) C. Chr. Stilwell Rd.—Young. First record for Burma.

C. pannosus (Mett.) C. Chr. Tenasserim—Parish.

C. nudus (Gies.) C. Chr. Between Bhamo and Tengyueh—Rock 7825.

C. heteractis (Mett.) C. Chr. Between Sadon and Yunnan border—Rock 7491; Sin Lum Kaba—329, 356, 373, 397; Thandaung—65, 6713, 6781.

C. lanceolatus (L.) Alston. Mergui—Parish; Rangoon—164; Mt. Popa—557; Maymyo—417; Namkham—298; Stilwell Rd.—Young 18.

C. spissus (Bory) Desv. Tavoy—7989; Rangoon—6560, 8033, 8050; Syriam—464; Moulmeingyun—6921; Maubin Distt.—8056.

C. confluens (R. Br.) C. Chr. Tenasserim—Parish; Kyain, Amherst Distt.—6872.

C. nummulariaefolius (Sw.) C. Chr. Tavoy—Parish; Taung Thonta, Tavoy—8016; Namkhok State—fairly common.

C. angustatus (Sw.) Desv. Madremacan, Mergui—Parish.

60. **Drymoglossum** Presl

D. piloselloides (L.) Presl. Tavoy and Mergui—Parish; Kyaukme Taung, Tavoy—8008; Rangoon—106, 6699.

LOXOGRAMMACEAE Ching
(Ching 1940b)

61. **Loxogramme** Presl

L. lanceolata (Bl.) Presl. Stilwell Rd.—Young. First record for Burma.

L. chinensis Ching. N'Bapa, Burma-Yunnan border—290. First record for Burma.

L. involuta (Don) Presl. Namkham—249; Mogok—264; Sin Lum Kaba—336.

L. avenia (Bl.) Presl. Mongnai, S S S.—7854. First record for Burma.

ANTROPHYACEAE Ching
(Ching 1940b)

62. **Antrophyum** Kaulf.

A. coriaceum (Don) Wall. Mergui—Clarke; Mogok—140.

A. obovatum Baker. Between Sadon and Yunnan border—Rock 7501.

A. parvulum Blume. Sin Lum Kaba—399. First record for Burma.

A. rectulatum (Forst.) Klf. Tenasserim Distt.—Parish; Stillwell Rd.—Young.

VITTARIACEAE Presl emend.
(Ching 1940b)

63. **Vittaria** Smith
(Ching 1931e)

V. elongata Sw. Moulmein—Parish 83, 513; Moulmeingyun—6912.

V. merrillii Christ. Stilwell Rd.—Young. First record for Burma.

V. sikkimense Kuhn. Kalama Taung—Parish; Moulmein—Clarke; Tenasserim—Beddome; Pang Yang, Manglun State—9762; between Sadon and Yunnan border—Rock 7419.

V. caricina Christ. Mergui—Wight; between Sadon and Yunnan border—Rock 7395.

V. linearifolia Ching. Upper Burma—G. Forrest 26550.
V. flexuosa Fée. Thandaung—6746. First record for Burma.
V. scolopendrina (Bory) Thwait. Rangoon, Cabin Island in Victoria Lake. First record for Burma.
V. amboinensis Fée. Martaban—Beddome; Kalama Taung—Parish.
V. himalayensis Ching. Sin Lum Kaba—355. First record for Burma.
V. doniana Hieron. Between Sadon and Yunnan border—Rock 7423; Haka, Chin Hills—7368, 7557, 7580, 7696.
V. doniana var. *angusta* Hieron. Between Sadon and Yunnan border—Rock 7398.

ELAPHOGLOSSACEAE Ching
(Ching 1940b)

64. **Elaphoglossum** Schott

E. petiolatum (Sw.) Urban. N'Bapa, Burma-Yunnan border—393. First record for Burma.

HYMENOPHYLLACEAE
(Copeland 1933, 1937, 1938)

65. **Cephalomanes** Presl

C. javanica (Bl.) van den Bosch. Madremacan, Mergui—Parish; Zinyaik, Martaban—Maymyo Herb. 13429; Kyain, Amherst Distt.—6868.

66. **Crepidomanes** Presl

C. bipunctatum (Poiret) Copel. Moulmein—Parish.
C. latealatum (v. d. B.) Copel. Haka, Chin Hills—7559. First record for Burma.
C. latemarginale (Eaton) Copel. Moulwein—Parish.
C. plicatum (v. d. B.) Copel. Burma—Beddome.

67. **Hymenophyllum** Smith

H. barbatum (v. d. B.) Baker. Between Sadon and Yunnan border—Rock 7442; Stilwell Rd.—Young.

68. **Mecodium** Presl

M. australe (Willd.) Copel. Tenasserim—Parish; between Sadon and Yunnan border—Rock 7445.
M. exsertum (Wall.) Copel. Tenasserim—Parish; Thandaung—11, 6761.
M. polyanthos (Sw.) Copel. Tenasserim—Parish; between Sadon and Yunnan border—Rock 7396.

69. **Meringium** Presl

M. denticulatum (Sw.) Copel. Moulmein Mts.—Parish; Stilwell Rd.—Young.

70. **Microgonium** Presl

M. henzaianum (Parish) Copel. Henzai Basin—Parish; Moulmein and Pegu—Parish.
M. motleyi (v. d. B.) Copel. Tenasserim—Beddome.
M. parvifolium (Bak.) Copel. Taungkya Tsakan, between Kaukareek and Myawadi—Parish.

71. **Vandenboschia** Copeland

V. auriculata (Bl.) Copel. Mergui—Maymyo Herb. 13482, Stilwell Rd.—Young 73, 88; Nam Tamai Valley, Burma-Tibet frontier—Ward 9151.
V. gigantea (Bory) Dickason. Stilwell Rd., Burma border—Young. First record for Burma.
V. pyxidifera (L.) Copel. Tenasserim—Parish.
V. radicans (Sw.) Copel. Mooleyit, Tavoy—Beddome; Sin Lum Kaba-Loiji Rd., 35th Mile—284.

DICKSONIACEAE

72. **Cibotium** Kaulfuss

C. barometz (L.) J. Sm. Near Mt. Nwalabo, Tavoy—Parish; Madremacan, Mergui—Parish;

Namkham—37; Mogok—150; Loije ford; Kengtung—9153; Pangyang, Manglun State—9793; Mongyai, N. S. S.—9628. One of the commonest ferns in Nanglum and Kentung States.

DENNSTAEDTIACEAE Ching
(Ching 1940b)

73. **Dennstaedtia** Bernhardi

D. scabra Wall. Namkham—251; Sin Lum Kaba—360, 392.

74. **Microlepia** Presl

M. hookeriana (Wall.) Presl. Stilwell Rd.—Young 201. First record for Burma.

M. trapesiformis (Roxb.) Kuhn. Kengtung State—Rock 2230; Thandaung—49; Stilwell Rd.—Young 150.

M. trichocarpa Ching ined. Sin Lum Kaba—337; Pangwai, Kengtung State—9416. First records for Burma.

M. firma Mett. Mogok—124, 130; Sin Lum Kaba—282; Haka, Chin Hills—7422. First records for Burma.

M. hirta (Kaulf.) Presl. Kengtung State—Rock 2088; Mogok-126, 127, 127A, 132; Sin Lum Kaba—346; Mt. Nwalabo, Tavoy—8223.

M. rhomboidea Presl. Stilwell Rd.—Young 201. First record for Burma.

M. pyramidata (Wall.) Lacaita. Stilwell Rd.—Young 75, 202, 203. First records for Burma.

M. marginata (Houtt.) C. Chr. var. *calvescens* (Hk.) C. Chr. Kengtung State—2180.

M. platyphylla (Don) J. Sm. Kengtung State—Rock 2232; Loimwe, Kengtung—509, 9113; Lamtok, Haka, Chin Hills—7680; Taungteik—7238.

M. kurzii (Cl.) Bedd. Kengtung State—Rock 2083; Mogok-Momeik Rd —153.

LINDSAYACEAE Ching

75. **Lindsaya** Dryander

L. cultrata (Willd.) Sw. Madremacan, Mergui—Parish.

L. malabaricum (Bedd.) Bak. Oktada, Martaban Hills, Kalama Range—Rock 750; Stilwell Rd.—Young 204.

L. orbiculata (Lam.) Mett. Stilwell Rd.—Young. First record for Burma.

L. lancea (L.) Bedd. Rangoon (cultivated)—456.

76. **Schizoloma** Guadichaud

S. ensifolia (Sw.) J. Sm. Moulmein—Parish; 575; Ka-lein-aun, Tavoy Distt.—8020; Kyaukme Taung, Tavoy Distt.—8007.

77. **Stenoloma** Fée

S. chusanum (L.) Ching. Kengtung State—Rock 2078; Loimwe, Kengtung State—9105; Pangyang, Manglun State—8074; Namkham—38, 221, 225, 263; Sin Lum Kaba—278, 279, 285; Thandaung—6721; Stilwell Rd.—Young 206.

DAVALLIACEAE Gaudichaud
(Ching 1940b)

78. **Davallodes** Copeland

D. membranulosum (Wall.) Copel. Loimwe, Kengtung State—521. First record for Burma.

79. **Acrophorus** Presl

A. stipillatus (Wall.) Moore. Between Sadon and Yunnan border—Rock 7392; Haka, Chin Hills—7506.

80. **Leucostegia** Presl

L. immersa (Wall.) Presl. Tenasserim Distt.—Parish; Thandaung—57; Mt. Popa—564; Taunggyi—8683; Loimwe, Kengtung—518.

L. faberiana (C. Chr.) Ching. Between Sadon and Yunnan border—Rock 7418.
L. hymenophylla (Parish) Bedd. Moulmein—Parish.
L. pulchra (Don) J. Sm. Moulmein—Parish; Mt. Popa—539, 540.
L. dareiformis (Hk.) Bedd. Dauna Taung—Parish; Moulmein—Clarke.

81. **Humata** Cavanilles

H. assamica (Bedd.) C. Chr. Stilwell Rd.—Young 207. First record for Burma.
H. alpina (Bl.) Moore. Mergui and southwards—Parish; road between Amherst and Tavoy—San Tun Yin.
H. griffithiana (Hk.) C. Chr. Loije ford, Burma-Yunnan border—409; Loimwe, Kengtung State—9165; Stilwell Rd.—Young 65. First records for Burma.

82. **Davallia** Smith

D. pectinata (Sm.) Desv. Mergui southwards—Parish.
D. bullata Wall. Mergui—Parish; Mogok—142; Loimwe, Kengtung—522.
D. lorrainei Hance. Kalaw (Pipe line)—26. First record for Burma.
D. denticulata (Burm.) Mett. Mergui—Parish; Tavoy—8051; Rangoon, Bird Island—192; Syriam—461; 461A; Maubin Distt.—8057.
D. solida (Forst.) Sw. Merwui—Parish.
D. solida var. *fijiensis* Diels. Rangoon (cultivated)—460.
D. speciosa Mett. Moulmein—Ind. Fil.

83. **Nephrolepis** Schott

N. acutifolia (Desv.) Christ. Tavoy—Parish.
N. biserrata (Sw.) Schott. Rangoon (cultivated)—158.
N. cordifolia (L.) Presl. Moulmein—Parish; Kyaukme Taung, Tavoy—8027; Toungoo—544; Mt. Popa—504, 543; Syriam—463; Nattaung, Karenni—9437; Taunggyi—8122A; Pangwai, Kengtung—7879, 9127; Stilwell Rd.—Young; Nam Tamai, Upper Burma—Ward 9179.
N. duffii Moore. Rangoon (cultivated)—156.
N. falcata (Cav.) C. Chr. Martaban—Parish; Kyaukme Taung, Tavoy—8237.

DIDYMOCHLAENACEAE Ching
(Ching 1940b)

84. **Didymochlaena** Desvaux

D. truncatula (Sw.) J. Sm. Ta-ok, in damp hollows—Parish.

PLAGIOGYRIACEAE Bower

85. **Plagiogyria** (Kunze) Mettenius

P. adnata (Blume) Bedd. Nattoung—Beddome.

MONACHOSORACEAE Ching
(Ching 1940b)

86. **Monachosorum** Kunze

M. subdigitatum (Bl.) Kuhn. Between Sadon and Yunnan border—Rock 7404.

HYPOLEPIDACEAE Ching
(Ching 1940b)

87. **Hypolepis** Bernhardi

H. punctata (Thbg.) Mett. Kengtung State—Rock 2387; Loimwe—9114; Namkham—261.

SINOPTERIDACEAE Koidzuma
(Ching 1940b)

Tribe 1. Cryptogrammeae

88. **Cryptogramma** R. Brown

C. brunoniana Wall. Adung Valley, 12,000 ft., Upper Burma—Ward 9919. First record for Burma.

Tribe 2. Cheilantheae

89. **Cheilanthes** Swartz

C. fragilis Hk. Moulmein (on limestone rocks)—Parish.
C. mysurensis Wall. Thandaung—6727; Manipur River below Falam—7552. First records from Burma.
C. belangeri (Bory) C. Chr. Moulmein—Parish; —568; Tavoy—7979; Rangoon—166, 469, 586; Twante—8045.
C. tenuifolia (Burm.) Sw. Tavoy—7987; Moulmein—569; Rangoon—586A; White Crow Lake, below Taunggyi—8183. First records from Burma.
C. argentia (Gmel.) Kunze. Mergui—Clarke; Zwakabin—Parish.
C. farinosa (Forsk.) Klf. sens lat. Zwakabin and Beloogewn (sea level)—Parish; Tavoy, 2500 ft —8028; Mt. Popa—554, 555, 6603; Taunggyi—36, 621; Wetwun—634, Sin Lum Kaba—265; Taingteik, Chin Hills—7553, 7554; Falam—7567.
C. farinosa var. *chrysophylla* Hk. Mergui—Clarke; Zwakabin—Parish.
C farinosa forma dalhousiae. Mt Popa—6603A; Mogok—119, Maymyo Herb.—581
C. farinosa var. nov Goteik Gorge—215. First record for Burma.
C. farinosa var. nov. Thandaung—56. First record for Burma.
C. rufa Don. Mergui—Clarke; Zwakabin—Parish; Mt. Popa—6611; Taunggyi—36, 183.
C. sp. nov. (near *subrufa* Bak.). Manipur River below Falam, Chin Hills—7551. First record for Burma.
C duclouxii (Christ) Ching. Kalaw—22; Taunggyi—182. First records for Burma.

90. **Doryopteris** J. Sm.

D. ludens (Wall.) J. Sm. Moulmein—Parish; Maymyo—105, Goteik Gorge—201, Mt. Popa—476, 6651; Webula, Chin Hills—7762.

Tribe 3. Onychieae

91. **Onychium** Kaulfuss

O. japonicum (Thbg.) Kunze. Ava—Hope.
O. lucidum (Don) Spreng. Loimwe, Kengtung—9149; Sin Lum Kaba—275, 327, 378; Falam, Chin Hills—7240; Haka—7707. First records for Burma.
O. siliculosum (Desv.) C. Chr. Amherst—Clarke; Kyain, Amherst Distt.—6863; Toungoo—Maymyo Herb.; Pyinmana—7113; Mogok—Momeik Rd.—118; Myitkyina; Kengtung State—Rock 2073.

PTERIDACEAE Ching
(Ching 1940b)

Tribe 1. Lonchitideae

92. **Pteridium** Gleditsch

P. aquilinum (L.) Kuhn. Mooleyit, foot of Mt. Nwalabo—Parish; Tenasserim—Hope; Mt. Victoria, Chin Hills—8596; Haka—7670; Mogok—134, 136; Kutkai—218; N'Bapa—262; Molahein Mt., Lawksawk State—8735; Loimwe, Kengtung—9147.
P. aquilinum var. *esculentum* Forst. Moulmein southward—Clarke; Maymyo—33; Taunggyi—472; 9006; Namkham—235; Mogok—134.

93. **Histiopteris** J. Smith

H. incisa (Thbg.) J. Sm. Kengtung Rd. at Salween River—9281. First record for Burma.

TRIBE 2. PTERIDEAE

94. **Pteris** Linn.

P. vittata L. Common everywhere—Parish; Kyain, Amherst Distt.—6899; Pyinmana—7112; Kalaw—21; Taunggyi—35, 184, 9012, 9298; Takaw, Kengtung State—9292; Maymyo—424; Mogok—109; Momeik State—147; Kalemyo—7209; Tiddim, Chin Hills—635.

P. cretica L. Amherst Distt.—Parish; Kalaw—5; Taunggyi—477; Loimwe, Kengtung—537; 9242; Maymyo—32; Sin Lum Kaba—372; Haka, Chin Hills—7546.

P. cretica var., or sp. nov. Sin Lum Kaba—353. First record for Burma.

P. heteromorpha Fée. Burma—Parish.

P. dactylina Hk. Tang-tung, Upper Burma-Vernay-Cutting Exped. 325 (Ward).

P. ensiformis Burm. Kengtung State—Rock 2031; Rangoon (cultivated)—556; Stilwell Rd.—Young.

P. griffithii Hk. Tamu, Upper Burma-Vernay-Cutting Exped. 10 (Ward).

P. pellucida Presl. Kengtung State—Rock 2246; Kyauktalon, Moulmein Distt.—6833; Stilwell Rd.—Young 42.

P. nervosa Wall. Amherst—Parish; Rangoon—636; Syriam—462; Pyinmana—7119; Mt. Popa—550, 551, 562; Sin Lum Kaba—348; Mogok-Momeik Rd.—111.

P. esquirolii Christ. Kengtung State—Rock 2188.

P. semipinnata L. Mergui, on the Tenasserim River—Parish; Stilwell Rd.—Young.

P. decrescens Christ. Goteik Gorge—206. First record for Burma.

P. grevilleana Wall. Stilwell Rd.—Young 59. First record for Burma.

P. khasyana (Cl.) Ching. Haka, Chin Hills—7311. First record for Burma.

P. fauriei Hieron. Pyinmana—7115; Taunggyi—473, 476; Namkham—N'Bapa—244; Mogok—114. First records for Burma.

P. fauriei var. *rigida* Hieron. Mogok—113; Kalemyo-Webula—7210; Haka—7571. First records for Burma.

P. argyraea Moore. Tenasserim Distt.—Parish; Kyaukme Taung, Tavoy—8235; Sin Lum Kaba—268; Mogok—101.

P. aspericaulis Wall. Zwakabin, Moulmein—7015; Bantai, Kengtung—9251; Stilwell Rd.—Young; Adung Valley, Upper Burma—Cutting Sikkim Exped. 9248 (Ward). First records for Burma.

P. excelsa Gaud. Burma—Parish.

P. longipinnula Wall. Burma—Ind. Fil.

P. longipinnula var. *hirtula* C. Chr. Valley of the Meh Len, Kengtung—Rock 2133 (type).

P. biaurita L. Moulmein and elsewhere in Tenasserim Distt.—Parish; Nwalabo, Tavoy—8211, 8019; Taungwine, Moulmein—6845; Kyauktalon, Moulmein—6838; Pyinmana—7124; Thandaung—61; Namkham—24, 227; N'Bapa—271; Mogok—637; Loimwe, Kengtung—524, 529.

P. linearis Poir. Kalaw—24A; Loimwe, Kengtung—9108. First records for Burma.

P. longipes Don. Tenasserim Distt.—Parish; Pegu—Clarke; Kengtung State—Rock 2179; Sin Lum Kaba—328; Mogok—121; Haka, Chin Hills—7272.

P. wallichiana Ag. Sin Lum Kaba—331. First record for Burma.

P. wallichiana var. *austro-siniea* Ching. Loimwe, Kengtung—9112. First record for Burma.

ADIANTACEAE Presl
(Ching 1940b)

95. **Adiantum** Linn.

A. parishii Hk. On top of limestone rock called Zwakabin, Moulmein—Parish; —7041.

A. philippense L. Everywhere on the plains—Parish; Kyaukme Taung, Tavoy—8026, 7992; Moulmein—574; Rangoon—10, 160, 470; Thandaung—48; Mt. Popa—549; Taunggyi—475.

A. soboliferum Wall. Anisakan Gorge, Maymyo—429. First record for Burma.

A. edgeworthii Hk. Fort Stedman, Inle Lake, S. S. S.—Hope; Taungyyi—474; Kalaw—25; Loimwe, Kengtung—510; N'Bapa—309; Sin Lum Kaba—306; Taungteik, Chin Hills—7246, 7565A.

A. caudatum L. Kungtung State—Rock 2329; Kengtung—9191; Taunggyi—9014, 9387; Mt. Popa—552, 553, 6607; Wetwun—63; Goteik Gorge—203; Mogok—146; Taungteik, Chin Hills—7241, 7246, 7565.

A. capillus-veneris L. Anisakan Gorge—416; Goteik Gorge—213; Kutkai—216; Kalemyo-Webula—7760; Yetagone, Chin Hills—7335; Taungteik, Chin Hills—7241; Ruavan, Haka, Chin Hills—7666.

A. cuneatum Langsd. & Fisch. Namkham (cultivated)—220.

A. flabellulatum L. Mong Yang, Kengtung State—9795; Namhka River, Manglun State—9794. First records for Burma.

A. trapeziforme L. Rangoon (cultivated)—157.

GYMNOGRAMMACEAE Ching
(Ching 1940b)

Tribe 1. Gymnogrammeae

96. **Taenitis** Willd.

T. blechnoides (Willd.) Sw. Amherst—Parish; Moulmein—Parish; Tenasserim—Beddome.

Tribe 2. Gymnopterideae

97. **Congiogramme** Fée

C. fraxinea (Don) Diels. Tenasserim—Parish; Chin Hills—Dickason.

C. petelotii Tardieu-Blot. Taunggyi—9382; Sin Lum Kaba—344. First records from Burma.

98. **Pityrogramma** Link

P. calomelanos (L.) Link. Tavoy—7976; Kyain, Amherst Distt.—6873; Rangoon—189, 585. First records for Burma.

99. **Hemionitis** Linn.

H. arifolia (Burm.) Moore. Tenasserim Distt.—Parish; Rangoon—159, 6572; Insein—8157.

ACROSTICHACEAE Presl emend.
(Ching 1940b)

100. **Acrostichum** Linn.

A. aureum L. Amherst—Parish; Rangoon (cultivated)—37.

CERATOPTERIDACEAE C. Chr.
(Ching 1940b)

101. **Ceratopteris** Brongniart

C. thalictroides (L.) Brongn. Moulmein—Parish; Kyaikto—6828; Rangoon—126, Myaungmya—6930.

MARSILEACEAE

102. **Marsilea** Linn.

M. brachycarpa A. Br. Pegu—Ind. Fil.; Pyinmana—542.

SALVINIACEAE

103. **Salvinia** (Micheli) Guettard

S. cucullata Roxb. Bhamo—4081. First record for Burma.

104. **Azolla** Lamarck

A. pinnata R. Br. Rangoon—Dickason. First record for Burma.

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A NEW SPECIES OF APLASTUS FROM IDAHO (COLEOPTERA: PLASTOCERIDAE)

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Aplastus acutus n. sp.

Male.—Narrow, elongate; moderately shining, light brown above and beneath; short, recumbent pubescence on both surfaces.

Head concave; surface coarsely, densely punctured; eyes moderately prominent; antennae extending beyond middle of elytra, scape short, stout, second segment slightly shorter than third, fourth segment twice as long as second and third together, fifth as long as fourth, sixth slightly longer than fifth, seventh, eighth, ninth and tenth same length as sixth, eleventh segment longest, fourth segment to tenth inclusive somewhat serrate.

Pronotum wider than long, widest at base; anterior margin lobed; basal margin sinuate; lateral margin sinuate, strongly divergent at hind angles; disk convex in middle, flattened along sides giving side margin a sharp carinate edge for its entire length, hind angle with fine carina parallel to lateral margin; surface densely punctured in middle, punctures slightly finer than on head, punctures finer and confluent at sides, obsolete at base. Scutellum small, oval.

Elytra wider than pronotum, elongate; sides subparallel, broadly rounded to suture at apex; surface with striae prominent at base and apex only, rest of elytra indistinctly triate; interspaces densely minutely punctate.

Beneath, prosternum carinate at middle with sutural carina on each side, prosternal process somewhat sulcate; surface coarsely, densely punctured. Abdomen shining, densely, finely punctate. All of tarsi longer than tibiae.

Length 17.5 mm.; width 4.4 mm.

Described from specimens collected by Otto Huellemann at Wallace, Idaho, April 14, 1940. The writer is indebted to Dr. H. F. Strohecker for the privilege of retaining holotype and paratypes; paratypes in the Strohecker collection.

The narrow elongate form, with long antennae and sharp lateral margins of pronotum will distinguish this species from closely related forms.

[1]Contribution from Department of Zoology and Entomology.

HIGH MUTANT GENE FREQUENCIES IN A POPULATION OF DROSOPHILA IMMIGRANS

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The biology of *Drosophila immigrans* with particular reference to the genetic structure of several populations from widely separated points in the U. S. A. formed the subject of an earlier report (Spencer 1940). It is the purpose of this communication to present data on the genetic analysis of a Western Pennsylvania population of this species in which two mutant genes were present in high frequencies. The analysis also serves as a basis for a discussion of the method of inbreeding by F_1 pair matings as a means of studying the genetic structure of *Drosophila* populations in regard to the recessive visible mutations carried in heterozygous form in wild flies.

THE POPULATION SAMPLE

On September 9th, 1944, three open traps consisting of large tin cans containing over-ripe tomatoes as bait were set in an open woodland near a stream within the environs of New Wilmington, Pennsylvania, a village a few miles from the Ohio-Pennsylvania border and located in Lawrence County. On the morning of September 11th flies from these traps were collected. The catch included many flies of the species, *Drosophila immigrans*.

As pointed out in the earlier report this species, which is tropical or sub-tropical in origin, is a highly successful introduced form throughout the U. S. A. It is more tolerant of low temperatures than *Drosophila hydei*, *melanogaster* and *simulans*, but is probably killed off outdoors in the latitude where the collection was made during severe winters. The peak populations of *D. immigrans* are found in the northeastern part of the U. S. A. in the autumn, at which time small over-wintering foci have bred up to a maximum, feeding on rotting tomatoes and other vegetables, windfall fruit and garbage. The species may be taken in woodland areas at considerable distances from human habitations during the autumn but certainly larger populations are found in gardens and orchards than in the woods

In the village where the sample was collected *D. immigrans* was observed in great abundance in tomato patches and on windfall fruit. It seems likely that the flies taken were recent migrants from surrounding gardens and orchards. The abundance of the autumn population was not necessarily correlated with the size of the over-wintering focus from which it came, but rather with favorable conditions of temperature, moisture and food supply during the summer and particularly in late summer and early autumn. In some years and areas *D. immigrans* may be scarce even in autumn and it has been the author's experience from many collecting records that the distribution of the species from year to year and place to place is much spottier than that of *D. melanogaster*.

THE F_1 GENERATION

Fifty-six pair matings of flies from the collection were made up in three-fourths ounce cream bottles containing the usual cornmeal, molasses, agar medium heavily enriched with brewer's yeast. To supply larvae with optimum conditions for feeding and pupating a modification of the method described by Spencer (1943) was used. After six days the parent flies were removed from the creamers and one-third of a double sheet of kleenex paper, soaked in a suspension of baker's yeast in water, was added to each creamer. Larvae burrow readily through the paper, find an abundant yeast supply for feeding, and an optimum place for pupa-

tion at the surface of the mat of paper. *D. immigrans* is a fly at least three times the size of *D. melanogaster*. With the technique used, in 24 cultures chosen at random from the total there emerged 1659 ♂♂ and 1632 ♀♀, an average of 133 flies per creamer. Furthermore, these flies were of uniform and normal size, and showed no evidence of overcrowding in the larval stage. The method of culture is recorded as it seems important in population studies to provide optimum culture conditions in small containers which are easily handled and occupy a minimum of space.

Out of the 56 pair matings 55 produced offspring. The flies from 24 of these cultures were carefully examined under the binocular microscope for visible abnormalities and all of these tabulated. In 20 of the 24 cultures one or more of the flies showed small extra sections of wing-vein near the distal end of the second longitudinal vein. 73 ♂♂ out of 1659 examined and 89 ♀♀ out of 1632 showed this character. In 4 of the cultures the character did not appear in the F_1. In 6 to 8 F_1 pair matings made up from each of these 4 cultures the character failed to appear in the F_2 flies from two of these cultures but did show in a few F_2 flies from the other two. This character has been found repeatedly in other populations of *D. immigrans*, and several more extreme net-venation mutants have been recov-

TABLE I

DORSO-CENTRAL BRISTLE COUNTS ON OFFSPRING OF 24 PAIR MATINGS OF WILD *Drosophila immigrans* FROM NEW WILMINGTON, PA.

Total males, 1,659; total females, 1,632. An equal or greater asymmetry in extra bristles would occur by chance less than once in 100 times.

	Extra Dorso-centrals				
	Left	Right	Both	Total Left	Total Right
Males	81	56	36	117	92
Females	185	138	111	296	249
Total	266	194	147	413	341

ered. It seems evident that extra-venation is a species-specific variant in *D. immigrans*. Wild flies of the species frequently show slight extra-venation and even more of them carry genetic factors capable of forming net-veins when made homozygous or acted on by modifiers.

An even more common variant among F_1 flies was the presence of extra dorso-central bristles. 23 of the 24 F_1 cultures showed this character, but in very different proportions. Table I gives a summary of the incidence of the character among the F_1 flies from the 24 cultures. The character appears more frequently and is more strongly expressed in females. Among the flies examined the character showed a definite asymmetry, appearing on the left side significantly more often than on the right. Tests and counts in later generations were not made and no explanation of this peculiar asymmetry was found. Like "extra-veins" this character is often met with in *D. immigrans* populations. While extra dorso-central bristles are not uncommon among wild flies of certain other species of *Drosophila*, for example *D. melanogaster* (see Dubinin, Romashov, Heptner and Demidova 1937), they are even more frequent in *D. immigrans*. It is clear that "extra dorso-centrals" has an inherited basis, and several loci may be involved. However, it is possible to find strains of this species in which the character is virtually absent.

Both "extra-veins" and "extra dorso-centrals" would seem to be species-specific variants in *D. immigrans*, highly variable in expression, found in many populations and in large numbers of flies, and probably subject to the action of genetic modifiers. Populations of this species not containing these variants are apparently more rare than those which carry them.

Among the F_1 flies of pair mating (26) there appeared many individuals showing stubble bristles. As all P_1 flies had been examined when pair matings of them were made and none had shown this character distinctly it seemed likely that both of the parents of culture (26) had been heterozygous for "stubble." This would indicate a high frequency of the stubble gene in the population, which was subsequently proved by further analysis.

THE F_2 GENERATION

From the offspring of each of the 55 P_1 pairs of flies either 7 or 8 F_1 pair matings were made up, using the same culturing technique as described above. Where one of a pair of flies mated together carries a recessive visible gene in heterozygous form half of the F_1 offspring should carry this visible gene but none should show the character. The mating may be represented as VV x Vv, where (v) is the gene for the recessive visible and (V) its dominant allele. The offspring will be VV and Vv in approximately equal numbers. The chance then of an F_1 pair mating being of the favorable type, Vv x Vv, to produce some (vv) flies showing the visible phenotype in the F_2 will be $.5 \times .5 = .25$. The chance of a pair mating not being favorable will therefore be $1 - .25 = .75$. When two F_1 pair matings are made up the chance of neither of them showing the character in the F^2 flies will be $.75^2$ and the chance of at least one of them showing it will be $1 - .75^2 = .437$. The more F_1 pair matings made up the more chance there will be of recovering the visible character among the F_2 offspring of at least one of them.

Table II gives the results of the inbreeding test. Only the first 7 F_2 cultures are recorded even where 8 were reared. Of the 55 P_1 matings only those from which visible mutations were recovered are listed in the first vertical column to the left. The first F_1 matings form the second vertical column, the second F_1 matings the third vertical column, etc. Whenever a mutant was recovered from an F_1 mating it is recorded in the table.

The total number of mutants recorded in each vertical column is found at the bottom of the table. Some investigators have held that the subjective error involved in recovering visibles from a population is so great that data on visibles will be very inaccurate. Tables such as the one shown make possible an objective test of this error. Since the same mutant will often turn up repeatedly in several of the F_2 cultures, if the mutant is found in one of the early pair mating cultures examined it will not likely be missed in later ones where it is present. However, if the investigator is overlooking mutants in the early cultures examined he may still see them in the later cultures. Such errors would then tend to give more mutants recovered in the last cultures examined than in the first ones. Since the summary at the bottom of Table II indicates as many mutants recovered from the first three vertical columns as from the last three this error was not present. It should be remembered that 25% of the flies in a given culture are on Mendelian expectation homozygous for the mutant when both parents are heterozygotes. Even where mutant types have lowered viability or incomplete penetrance several to many flies out of the 100 or more flies in the culture will show the character. It is of course true that some mutants will have such a low penetrance and/or viability that they may be missed. Others will require special environmental or genetic tools for their demonstration. Obviously the mutants recovered represent only a fraction of the total genetic changes in the population. But for comparative purposes there is a large class of visibles which may be dealt with objectively with relatively

TABLE II

Analysis of 55 P_1 Pairs of *D. immigrans* from New Wilmington, Pa., by 7 F_1 Pair Matings Each.

Mutants appearing in F_2 cultures shown.
Only numbered P_1 pairs from which mutants were recovered tabulated.

P_1	F_1-1	F_1-2	F_1-3	F_1-4	F_1-5	F_1-6	F_1-7
2	—	—	—	brick		—	—
4		—	eyeless	—	—	brick	—
5	minute	—	stubble	—	minute	—	—
6		—	—	stubble	—	—	stubble
9	—	brick	—	—	—	—	
15		dubonnet	—	—	stubble	—	—
17	—	—	brick	—	brick	—	—
18	—	—	stubble	stubble	—	—	stubble
19	brick	brick	—	—	—	—	—
21	—	—	—	—	—	stubble	
22	—	stubble	brick	stubble	—	—	—
24	—	—	—	stubble	stubble	—	—
(26)	stubble	—	stubble	(stubble)	stubble	—	—
28	—	—	—	—	sepia-spineless	—	—
29	—	brick		—	—	—	—
30	stubble	stubble	—	—	—	—	—
32	broken	stubble	broken stubble	broken	—	broken	purple-net-short
33	—	—	—	—	stubble	stubble	—
34	—	—	tiny	—	—	tiny	tiny
35	—	—		—	—	—	stubble
36	—	dubonnet	—	—		dubonnet	—
38	—	—	—	—	brick	—	—
40	stubble	—	—	—	stubble	—	stubble
42	double	—	—	double	—	double	—
43		—	stubble	—	stubble	—	stubble
46	2-brist.	2-brist. stubble short-5	—	stubble	2-brist. short-5	short-5	short-5
47	—	stubble	—	—	—	stubble	—
48	—	—	small	—	—	—	—
51	stubble	—	—	purplish-thin-sing.	—	stubble	stubble
52	—	stubble	stubble	—	—	—	—
Total	9	13	12	10	12	10	9

Note: Both parents of P_1 (26) were heterozygous for stubble. Both parents of F_1 26–4 were homozygous stubble.

small error under good culture conditions and in the hands of a competent observer.

In Table III the percentages of visibles which should be recovered out of the total visibles present in a given sample where one to five F_1 pair matings are reared are given. The table also shows the number of mutants actually observed and those expected in the sample analyzed It will be seen that 36 mutants were recovered in the first 5 F_1 pair matings from the 55 P_1 pairs. This, as shown by the table, should be 76.3% of all those present. As the observed and expected frequencies for 1–4 pair matings indicate the validity of the method it is possible to estimate that there were about 47 visibles of the kind being studied actually present in the sample When 7 pair matings are reared 87% of the total number of mutations should be found. Thus 11% or about 5 of the 47 mutations should be recorded for the first time in columns 6 and 7. Actually 4 mutations do appear here for the first time and we may assume that the 7 not found at all were present in the sample. On the average not quite one visible mutant in heterozygous form was carried per pair of flies tested. These data indicate that the total number of visibles of the kind being studied can be accurately estimated for a population sample by the method of rearing one or more F_2 cultures from F_1 pair matings of the wild pairs of flies constituting the sample.

TABLE III

OBSERVED AND EXPECTED NUMBERS OF MUTATIONS RECOVERED BY REARING 1, 2, 3, 4, AND 5 F_1 PAIR MATING CULTURES OF 55 PAIRS OF WILD *Drosophila immigrans*

(See text for full explanation.)

F_1 PRS.	EXPECTED PER CENT OF MUTATIONS RECOVERED	NOS. OF MUTATIONS RECOVERED	
		Expected	Observed
1	25%	11 8	9
2	43 7%	20 6	19
3	57 8%	27 3	28
4	68 4%	32 2	32
5	76 3%	36 0	36

TABLE IV

A LIST OF THE DIFFERENT MUTATIONS FOUND IN THE NEW WILMINGTON SAMPLE. ALL AUTOSOMAL RECESSIVES; STUBBLE INCOMPLETE RECESSIVE.

Eye colors
- (1) brick
- (2) dubonnet

Wing veins
- (3) broken
- (4) cross-veinless
- (5) short—5

Bristle changes
- (6) double
- (7) minute
- (8) small
- (9) stubble
- (10) tiny
- (11) two-bristle

Phenotypic Complexes
- (12) purple eye—net wings—short wings
- (13) purplish eye— thin bristles—singed hairs
- (14) sepia eye- spineless bristles

DESCRIPTIONS OF MUTATIONS FOUND

A list of the mutations found is given in Table IV. For comparative purposes a short description of each mutation is given below. As most of the stocks were

soon discarded no symbols have been assigned to the mutations. Similarity between any phenotype and that of a mutation previously recorded in this species is mentioned. The reader is referred to Table II and descriptions of mutations in a former publication (Spencer 1940).

EYE COLORS—

(1) Brick. Austomal recessive. A dark reddish brown eye-color easily distinguished from the vermilion-like wild-type at all ages. Excellent viability. Recovered 8 times.

(2) Dubonnet. Autosomal recessive. A purplish eye-color completely separable from wild-type but only under proper lighting conditions. Good viability; female sterile. Recovered twice.

WING VENATION—

(3) Broken. Autosomal recessive. Breaks in second, third, and fourth longitudinal veins. Wings may be spread. Some hairs removed lateral to dorso-central bristles. Variable expression with normal overlaps.

(4) Cross-veinless. Autosomal recessive. Anterior cross-vein always missing; posterior cross-vein missing or broken. Developmental period lengthened several days at 22 C. Fair viability and fertility.

(5) Short–5. Autosomal recessive. Distal end of fifth longitudinal vein missing. Second longitudinal may be short and posterior cross-vein broken. Variable with normal overlaps.

BRISTLES—

(6) Double. Autosomal recessive. Two or three bristles from one basal ring Sometimes only one small bristle or none from basal ring. Most often affects anterior scutellars, then posterior scutellars and dorso-centrals. Apparently reduplication and loss are diverse phenotypic manifestations of the spreading of bristle forming material. A similar case is reported in the phenotypic expression of the mutant, engrailed, in *D. hydei* (Spencer 1942).

(7)) Minute. Autosomal recessive. Bristles about two-thirds normal length and correspondingly reduced in thickness. Good viability. Less extreme than minute from Camp Rincon, Southern California.

(8) Small. Autosomal recessive. Bristles about three-fourths normal length. Developmental period of flies lengthened.

(9) Stubble. Autosomal, incomplete recessive. All bristles short and heavy as in Stubble of *D. melanogaster* (Bridges and Brehme 1944). Slight effect in heterozygotes. Homozygotes easily separable from heterozygotes Excellent fertility and viability. Similar to stubby from Woods Hole, Massachusetts and stubby-like from Gatlinburg, Tennessee. Recovered 19 times.

(10) Tiny. Autosomal recessive. Bristles similar to (8) above, but entirely sex-limited to male.

(11) Two-bristle. Autosomal recessive. Anterior dorso-centrals missing. A few normal overlaps.

PHENOTYPIC COMPLEXES—

(12) Purple-net-short. Autosomal recessive. Purple eye; plexus of veins around posterior cross-vein or posterior cross-vein missing; wings short. This complex semi-lethal and sterile.

(13) Purplish-thin-singed. Autosomal recessive. Dark purple eye; short, thin bristles; hairs singed and sparse; legs misshapen. This complex semi-lethal and sterile.

(14) Sepia-spineless. Autosomal recessive. Sepia eye; bristles very small, some missing; flies soon die. This complex semi-lethal and sterile.

GENE FREQUENCY OF "STUBBLE" AND "BRICK"

The most interesting fact discovered in the course of this analysis was the high frequency of the gene, "stubble," in the sample and therefore presumably in the population from which the sample was drawn. "Stubble," a non species-specific character was recovered 17 times in the first 5 F_2 cultures of the P_1 matings. As 76% of the mutants present in the sample are recovered by 5 F_1 pair matings, then "stubble" was present in about 22 of the 110 flies analyzed or in 20% of these flies. As each fly carries two genes at the stubble locus this gives "stubble" a gene frequency of 10% in the sample and presumably in the population. This is a higher frequency for a given gene, either visible or lethal, than any hitherto reported for any population of any species of *Drosophila* yet investigated, excepting of course species-specific characters widespread in all or most populations of a species. Over 50 populations from the species *D. melanogaster*, *pseudoobscura*, *subobscura*, *phalerata*, *transversa*, *hydei*, *robusta*, *immigrans* and perhaps a few others have been studied on as large or a larger scale than the population under consideration.

The variety of structure revealed by these several populations would lead to the prediction that in a population of populations some might be found with specific gene frequencies as high as that reported here. While the samples have often been inadequate to give an accurate picture of low gene frequencies at specific loci they have been sufficiently large to reveal such a high frequency as here found if it had been present.

It becomes of interest to consider the possibilities of population structure, ecology and selection pressure which might account for the present case. One may consider the possibility that heterozygous "stubble," which has a slight phenotypic effect on bristles, actually maintained a selective advantage in the 1944 summer population of *D. immigrans* in the New Wilmington environment. Some might argue that a laboratory experiment could answer this question. This position fails to take into account the fact that it is next to impossible to simulate a natural environment in laboratory culture, particularly when that environment contains many unknown variables. Even in the relatively controlled environment of the greenhouse economic entomologists have often found it extremely difficult to furnish environmental complexes sufficiently similar to transplant successfully a greenhouse pest thriving at one place to a new environment. It is possible that a selective advantage of heterozygous "stubble" was present under the particular summer environment to which the New Wilmington, 1944, population was subjected. An approximate equilibrium of 10% "stubble" to 90% wild-type might conceivably have been reached in this particular environment by early September, 1944. It seems likely that the change in conditions from the warm, relatively dry summer to the cold, wet autumn would upset such an equilibrium before or soon after it became established. The author considers that the postulated selective advantage of "stubble" is a possible explanation of the gene frequency but not a probable one.

It might be argued that the sample represented the immediate offspring of a very few flies one or more of which were heterozygous for "stubble." As the sample was taken in a woodland lot where there were no concentrated food stores it seems unlikely that this explanation is valid. Rather it would seem that the sample represented for the most part migrants from surrounding orchards and gardens. It is quite possible that these sub-populations from which the sample was drawn would have shown large fluctuations in the incidence of "stubble." We may then assume that the surrounding population contained a 10% frequency of "stubble" or that one or more of the sub-populations contained a considerably higher percentage.

Without postulating a selective advantage of heterozygous "stubble" we may

find a valid explanation in the population structure of *D. immigrans* in this latitude. Spring collection records indicate that this species is winter-killed outdoors in this latitude at least in some winters. The population of a village will then pass through a sharp bottle-neck consisting of a relatively few individuals passing the winter in one or a few fruit-cellars or similar environment. Not every home harbors a winter population of *Drosophila* and the chance element in such overwintering is indicated by the species found from winter to winter. In the author's basement a few winters ago a small population of *D. funebris* survived until spring. This was the only species present. This winter a small population of *D. melanogaster* will survive if the housewife doesn't find the can of fruit, the metal top of which has rusted through. No other species is present.

After the overwintering of a few flies in some basement of a village home the bulk of a spring population may well be established from one or a few females which first reach a favorable outdoor breeding ground. The high incidence of "stubble" in this population might well have resulted from the chance concentration of the stubble gene through two or more of these winter bottlenecks. As more populations of *Drosophila* are investigated even higher gene frequencies in individual populations may be discovered. They will probably be found in populations undergoing sharp seasonal reductions.

In this connection the following case is of interest. Some years ago Dr. Harrison Stalker exposed a *Drosophila* trap, consisting of an open half-pint milk bottle containing banana mash, in a woodland park in Wooster, Ohio. The trap was brought into the laboratory after about a week and contained many *Drosophila* larvae This group of larvae might be considered a small sub-population of *Drosophila*. When reared out the flies were mostly of the species, *D. simulans*, which has a very spotty distribution in this latitude. More remarkable was the fact that a large proportion of the flies showed a visible wing vein character, a conspicuous break in the second longitudinal vein. This turned out to be an autosomal recessive and the incidence of homozygotes indicated that they probably came from a pair of flies both heterozygous for the wing-vein gene. Thus this micro-population probably contained the mutant gene in a frequency of approximately 50%. Conceivably the 100 or more flies from this open trap might have established a local sub-population of *D simulans* with an extremely high frequency of a specific mutant gene

Further evidence on the small effective breeding size of the New Wilmington *D. immigrans* population is gained from the incidence of the eye-color gene "brick." This gene was recovered 7 times in the first 5 F_1 matings indicating its presence in the sample about 9 times or a gene frequency of about 4%. While the sample is probably inadequate to establish accurately the frequency of "brick" in the population, yet its repeated recovery is further evidence in favor of the postulated population structure. Another eye-color, "dubonnet," was found twice.

Seven of the "stubble" recurrences were tested for identity by cross-tests and all proved to be identical or indistinguishable alleles. A test of 4 of the "brick" recurrences showed them to be identical. With the distinct phenotypes of "stubble" and "brick" it was thought that the above test was sufficient to establish the allelism of the recurrences found. When genes reach this frequency in a local population they may persist for years. Thus the gene for vermilion eyes, a sex-linked recessive visible in *D. hydei*, attained a frequency of 6.5% in a sub-population of this species in Wooster, Ohio, in September, 1931 (Spencer 1932). This gene persisted in the local populations for at least 6 years.

This *D. immigrans* population represents an extreme variant in the population of *Drosophila* populations thus far investigated in regard to the high frequency of a single mutant gene. It indicates that under certain environmental conditions population structure may be such as to favor the rise to high values of specific gene frequencies. It is conceivable that "stubble" in heterozygous condition also had

a selective value under the particular environment to which the population was subjected. The genetic analysis of the population gave no information on the relative roles of selection, mutation rate, population size and migration. For a theoretcial discussion of the roles of these factors the reader is referred to the publications of Dr. Sewall Wright (1931; 1937). Based upon an ecological study of the species in the latitude in which this population was found the author considers that the breeding structure of the population, with sharp seasonal fluctuations in size, was probably the main factor in determining the frequency of the gene, "stubble," in this Western Pennsylvania population of *D. immigrans* in September, 1944

SUMMARY

A population sample of *Drosophila immigrans* was collected from three traps exposed in a woodland lot in the village of New Wilmington, Western Pennsylvania, in September, 1944.

From 55 pair matings of the wild flies F_1 cultures were reared; 24 of these were examined for variants and showed a high incidence of "extra venation" and "extra dorso-central" bristles, both of which are species-specific characters generally encountered in populations of this species

"Extra dorso-centrals" was found more often in females and showed a marked asymmetry in both sexes.

In one F_1 culture "stubble" bristles, an autosomal, incomplete recessive appeared in homozygous form in many flies

Analysis of the sample by 7 F_1 pair matings from each P_1 culture resulted in the recovery of 14 different visibles. Each of these is described.

A study of the data indicates that about 47 visible mutant genes, counting recurrences, were present in the 110 flies constituting the sample

The gene, "stubble," on the basis of the number of times recovered, is estimated to have had a frequency of about 10% in the population sample.

The gene, "brick," was recovered 7 times and "dubonnet" twice.

As "stubble" showed a slight phenotypic effect in heterozygotes the possibility that it might have had positive selective value is considered.

Extreme reduction in population size resulting in chance fluctuation of gene frequencies is considered the probable explanation of the high incidence of "stubble."

Other cases of high gene frequencies probably due to such seasonal bottlenecks are cited.

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DIFFERENTIAL STAINS OF INSECT TISSUES[1]

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In entomological work there is a great need for stains which will pick out specific organs and tissues. This is especially true for the work of gross dissection and the recognition of the boundaries and shape and form of the internal organs. In the dissection of mammals the lungs are pink, the muscles a darker pink, the liver a brownish red, the kidneys a grayish red, the testes yellow, etc. Few anatomists realize the tremendous positive aid such differences of color give the research student. In the insects, nearly all internal organs and tissues are white so that color values in the recognition and differentiation of parts are absent.

This lack of color help has tended to limit studies of the internal anatomy of insects to the larger organs, such as the sexual, digestive, muscular and nervous systems. A review of the literature shows that the heart has seldom been observed even in some elaborate published studies of internal organs. The heart wall is one cell thick! This organ actually disappears in many dissections especially of preserved material.

This review of stains for specific tissues and organs is a first attempt to locate stains which when injected in dilute solution into the live insect color only specific organs against the general white background. This procedure would be classed as intra-vitam staining. It prepares the internal structure for gross dissection.

It was found necessary to develop a technique to include the handling of the subjects as well as the application of the material. One method has been worked out and will be explained along with the results produced by a number of stains in its application. In using a number of different stains it was found possible to determine to some extent whether those so-called "vital stains" from other fields of investigation could be so classified in entomology. In certain cases some were found usable that are not usually considered for viable tissue.

The use of the American cockroach *Periplaneta americana* for the experimental subject was due to its generalized structure and ready availability. For the purposes of a control other forms were used as will be explained.

The writer wishes to express her sincere appreciation for the guidance given by Dr. C. H. Kennedy of the Department of Entomology who, acting as adviser, counseled and encouraged the pursuit of this project. The aid and suggestions given in the obtaining of materials by Dr. G. W. Blaydes of the Department of Botany were also greatly appreciated.

Materials and Methods

Experimental animal.

The basic experimental subject was the American cockroach *Periplaneta americana*. Data were more easily obtained by using the adult form as the strength of solutions used was high and forms younger than six months of age did not survive except in a very small percentage. The sex of the insect did not prove to be a differentiating factor as was shown in a number of cases where the reaction to a stain was found to be identical in both the male and female forms. However, more males were used in the work because of the available supply and the sparing of some females for colony perpetuation.

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EQUIPMENT.

Small size battery jars served as retaining chambers for insects undergoing the tests. Each housed only those subjects containing one of the stains. The jars were marked as to the stain being used as well as the date of injection. From each were taken the subjects that had passed the time interval required, for each observation stage. These were examined, and then the data recorded.

Three materials were used for lessening the activity of the experimental insects during the injection of the staining materials and at the time of the observational dissection. One of these was chloroform, the first used and least satisfactory. Its use was discontinued mainly due to the high mortality rate in the roach population. If the insects were left in the anesthetizing chamber a minute more than the time required to cause the cessation of rapid leg movement, the possibility of recovery was only 50 percent. More successfully used was ether. Complete cessation of movement (external) could be awaited with an expectation of 95 percent recovery. Complete relaxation of the insect being used permitted the injection of the stain and the transfer to the housing jar with an additional few minutes before visible activity was again evident.

When a number of roaches were required at one time or when excessive excitement in the culture prevented the easy removal of desired specimens, carbon dioxide gas was employed. The entire culture was exposed for one minute. After that only some head and leg movements were visible and the desired specimens could be removed and the gas driven off the remainder to permit recovery. The effect lasted one to five minutes and then normal activity was again observed.

For injection, pipettes scaled to deliver 2–3 cc. were first used, but these were abandoned, because the amount of staining material proved to be excessive and the internal organs were often injured as well as the cuticular body covering. A hypodermic needle (1 cc.) using a small needle was the replacement. With this 0.1 cc. injections were made.

Injection of the stain by means of a hypodermic needle proved to be not only the most successful means of application but also the easiest. The point of injection used throughout was at the base of the third abdominal segment on the ventral side, a little off the center of the body. In the attempts to use immature forms under six months the piercing of internal organs proved a serious cause of death.

A binocular microscope was employed to study the internal structures and the observations recorded. The insect was still alive while the dissection and subsequent study were made and it was possible to observe the reactions of the visceral structure (as parts of the digestive system and the heart).

EXPERIMENTAL TECHNIQUE.

The first step after the insect was removed from the stock culture was to apply an anesthetizing agent, preferably ether, until all violent external movement ceased. This was accomplished by placing the animal in a closed jar containing a small piece of cheesecloth saturated with ether. Then after being placed on a small dissecting pan and held steady by the investigator's hand, the hypodermic needle was inserted at the base of the third abdominal segment, and the stain being used was injected.

After the injection was made, the insect was placed in a housing jar properly labeled as to type of stain used and the date. As will be observed, a definite time interval schedule was set up. These were one-half hour, one day, two days, and three days. These periods were used not only as an equalizing measure but also as a test of speed and viability. After retention over the time interval desired, the dissection was made and the gross results obtained.

Before observation began ether was again used; then upon removal to a dissecting pan the legs and wings (if present, on female specimen) were removed. The body was opened by a slit through the center of the ventral side from the

base of the head to the tip of the abdomen. The body was then spread open and pinned so the internal area was entirely exposed.

All the stains used were made up at the percentage of one gram of dry material used to 100 cc. of normal salt solution. This was a fairly high concentration for staining material and may play a definite role in those types upon which it was impossible to obtain data except over a very short time interval. The problem arises in this connection as to what dilution the stains might be carried in order to obtain like results, but this was not determined.

Explanations

Terms.

V-shaped—The heart wing muscles: color extending along tracheae from the heart region in shape of a V with the large end toward the heart.

Fractions—Refer to percentages of total amount or number of particular organ or group of same type of organs affected.

All stains tested are classified under four headings:

1. Outstanding Results.
2. Results Fair.
3. Lack Good Results
4. Incompletes

Each stain is taken in order and has under it all organs and tissues that showed results. Those organs and tissues not mentioned were found to be of the normal color and condition. Opposite this listing or following it is the description of the appearance after a definite time interval that was allowed. All the stains are classified in the same intervals of time.

The findings classified under *Incompletes* have been the results of death appearing at the time intervals described. Under repeated testing the mortality rate continued to appear so high, it was found impossible to gain results at the concentration of staining material used.

Outstanding

Blue de Lyon O.

Two days testing proved best for number of structures shown and variation of color. The gizzard and crop were blue tinged; the heart light blue outlined; malpighian tubules pale blue to lavender; salivary glands very pale blue; and small intestine pale lavender. The thorax muscles were blue near the dorsal side while the fat bodies were blue about the injection point, and the dorsal wall material was blue (pale) for a short distance on either side of the heart. In half an hour the organs shown were the gizzard, caecae, heart outline, tracheae (partially), malpighian tubules, and intestines; in one day were shown the gizzard, heart outline, crop, edges of caecae, salivary glands, thorax muscles and digestive tract; for three days only the caecae and heart outline showed.

Aniline Blue.

Here half an hour gave the best results. Scattered portions of the fat bodies were light blue; the thorax muscles grey; the dorsal wall material a dead white. The caecae and tracheae (in the thorax) had faint blue outlines. The gizzard was blue tinged, the heart faintly so; while the salivary glands had a faint grey-blue tinge. After one day less distinction but some color was in a few fat bodies, malpighian tubules, heart outline, while the dorsal wall material and femurs were colorless; two days presented caecae, heart and crop; and the third, the heart and tracheae.

Azur II.

For structures half hour results are taken. Light lavender fat bodies, lavender outlined heart, and tracheae (color from heart) showed easily. The thorax muscles

were blue; salivary glands dark blue; caecae (swollen) blue; blue tinge on crop; and greenish blue on malpighian tubules. For color variance one day proved good. Here was easily seen the lower halves of the crop and gizzard, dorsal wall material, fat bodies, salivary glands, heart, and caecae; two days presented caecae, gizzard, intestines, fat bodies, salivary glands, malpighian tubules, and dorsal wall material; in three days was still shown the fat bodies, dorsal wall material, salivary glands, gizzard, and large intestine.

Brilliant Cresyl Blue.

Here two days testing proved best for structures and color. The gizzard, caecae, salivary glands, large intestines were lavender while the malpighian tubules were a mixture of this and yellow. The dorsal wall material was dark blue, the fat bodies bright blue with lavender marks; the heart blue-tinged (not all through thorax); the femurs green; and thorax muscles bluish-green; except for parts mentioned the digestive tract was deep blue. With half an hour the large intestine and most of the other internal structures were colored; with one day the gizzard, caecae, intestine, half the malpighian tubules, crop, fat bodies, dorsal wall material, heart, and salivary glands were designated; likewise on the third day

Toluidin Blue.

For structures and color one day timing proved most productive. Lavender was the color of the thorax muscles, salivary glands, while it tinged the crop and the gizzard. The tracheae were blue-tinged near the heart while the heart itself had blue outline varying from pale to dark. The ovaries were light blue and the fat bodies deep blue; the malpighian tubules and caecae green. In half an hour reactions were seen on fat bodies, caecae, salivary glands, gizzard, and heart; in two days thorax muscles, fat bodies about intestines, salivary glands, and dorsal wall material were clear; blue predominated with three days on fat bodies, salivary glands, and heart outline.

Trypan Blue.

With this stain half hour timing showed the most structures and color variance. The salivary glands and ovaries were pale lavender; the caecae blue tinged; the malpighian tubules lavender tinged. After one day the stomach, tracheae, and heart were shown; two days only the heart appeared touched; this was the same on the third day as the second.

Rose Bengal.

Three days timing proved most effective for showing the greatest number of structures. The crop and gizzard were deep red; the caecae orange-red; the thorax muscles red streaked. The salivary glands were deep pink while the ovaries were pink. The dorsal wall material was light scarlet, and half of the malpighian tubules and fat bodies were bright scarlet. The heart was deep wine. Two days was best for color variation. Here appeared the crop, gizzard, caecae, heart, dorsal wall material, salivary glands, ovaries, malpighian tubules, part of the fat bodies, and femurs; with half an hour all the insides were colored; one day showed dorsal wall material, malpighian tubules (most), tracheae, and ovaries with some other scattered coloring.

Results Fair

Biebrich Scarlet.

The most results were gained from one day tests. The heart, fat bodies and dorsal wall material were scarlet; the small intestine red; the malpighian tubules bright orange; and the salivary glands bright pink. Half hour testing produces the most color. There showed up the malpighian tubules, digestive tract, salivary glands, thorax muscles, and heart; two days showed malpighian tubules, heart, and

light outlining of the tracheae; three days produced results on dorsal wall material, heart, malpighian tubules, and salivary glands.

GENTIAN VIOLET IMP.

After one day the greatest color variance and results were obtained. Violet predominated, showing in the crop, gizzard, fat bodies, heart, dorsal wall material, small intestine, and caecae. The salivary glands were a deep lavender and half the malpighian tubules were lavender. After half an hour there showed the crop, gizzard, heart outline, salivary glands, malpighian tubules and fat bodies; with two days were traces on crop and some fat bodies; like traces were seen on the third day on salivary glands, fat bodies, gizzard, malpighian tubules, and small intestine.

CONGO RED.

Two days work was the best for structure and color results with this stain. Dark brown flakes were scattered in the body cavity. The fat bodies and dorsal wall material were orange-brown colored; crop and gizzard dark red-brown; the caecae dark red with a dull red coating over the heart; and the salivary glands dull lavender. Half an hour produced results on salivary glands, digestive tract, fat bodies, dorsal wall material, and heart; one day on salivary glands and gizzard, fat bodies, crop, and heart; three days on heart, caecae, malpighian tubules, and salivary glands.

BORDEAUX RED.

With this, one day brought more structures to attention. Pink predominated, being on the salivary glands, crop, gizzard, small intestine, and outer two-thirds of the tracheae. The malpighian tubules were dull red (granular in appearance) as was the heart (near the tracheae). The thorax muscles had a few red streaks. Half hour testing produced more color variance. Here showed up clearly the heart, salivary glands, malpighian tubules, caecae, dorsal wall material, and thorax muscles; two days showed caecae, small intestine, and heart; while three days showed salivary glands, fat bodies, crop, and heart.

SAFRANINE O.

With this stain more structures showed up in a day. The pink of the upper half of the crop, dorsal wall material, heart outline, fat bodies, and gizzard showed as deep pink on the salivary glands and thorax muscles. The small intestine and caecae were bright scarlet; the malpighian tubules bright orange. The color variance was best in two days. The salivary glands, caecae, malpighian tubules, thorax muscles, small intestine, and heart outline were seen; with half an hour was seen the malpighian tubules, crop, thorax muscles, and caecae, salivary glands, dorsal wall material and heart outline; in three days was seen these: small intestine, fat bodies, thorax muscles, salivary glands, and heart outline.

DAHLIA B.

Half hour results showed more structures and color. Two-thirds of the fat bodies, malpighian tubules, and sides of the heart were lavender; gizzard, salivary glands, and lower end of crop violet. In one day could be seen the salivary glands, half the fat bodies, dorsal wall material, and thorax muscles; in two days the anterior half of the fat bodies, heart, caecae, and a few malpighian tubules; in three days salivary glands, fat bodies, caecae and small intestine.

METHYL VIOLET B.

One day proved the optimum timing. The fat bodies, malpighian tubules, and dorsal wall material were colored rose lavender; gizzard and small intestine light violet. The salivary glands were lavender with violet colored "veins," and the heart outline was violet. Half hour results were for salivary glands, crop, gizzard, fat bodies, heart outline, and malpighian tubules; two days for heart outline (in

the thorax), caecae, salivary glands, digestive tract, and fat bodies; three days for large intestine, malpighian tubules, and *fat bodies.*

LIGHT GREEN S F YELLOWISH.

Half hour results were best on structure and color counts. The ovaries were spotted with pale green; the malpighian tubules brilliant green colored; the gizzard dark green as well as the heart outline; the salivary glands pale blue. The crop, dorsal wall material, and thorax muscles (at base of legs 1 and 2) were green tinged. In one day we find malpighian tubules, heart outline, salivary glands, femurs, gizzard, large and small intestines, and crop; two days find salivary glands, malpighian tubules, heart, crop, thorax muscles and small intestine, tracheae and femurs; three days find heart outline, dorsal wall of heart, half malpighian tubules, large intestine, and thorax muscles.

FAST GREEN F C F

Half hour work produced the greatest number of affected structures. Bright green predominated as shown in the fat bodies tinge, salivary glands, gizzard, intestines, and ovaries. There were traces of green on the crop and malpighian tubules as well as the tinge on the thorax muscles. Half the caecae were green; the heart covered with dark green; and the dorsal wall material had a blue-green tinge. Two days produced more color variation, on salivary glands, femurs, dorsal wall material, crop, gizzard, heart, caecae, tracheal outlines, malpighian tubules, fat bodies, and intestines; one day showed on fat bodies, malpighian tubules, femurs, dorsal wall material, crop, gizzard, intestines, heart, caecae, and stomach; three days on fat bodies, salivary glands, thorax muscles, heart, femurs, base of antennae, caecae, malpighian tubules, crop.

CHLOROZOL BLACK E.

Three days was best for structures. The crop, heart, tracheae (V-shaped outline), and femurs were black; the malpighian tubules, caecae and gizzard were grey with the fat bodies a dark grey as also the salivary glands. The dorsal wall material was almost black while the intestines had a dark lavender tinge. One day work had more color variation. Namely, on crop, heart, caecae, dorsal wall material, fat bodies, malpighian tubules, and salivary glands; half an hour on crop, fat bodies, dorsal wall material, salivary glands, malpighian tubules; two days on fat bodies, crop, malpighian tubules, salivary glands, and heart outline.

AZUR I.

One day proved best for structures and color here. The salivary glands were a true blue, while the thorax muscles were light blue; the malpighian tubules ranged from light blue to deep violet; and both the heart outline and the tracheae were blue tinged. Both the fat bodies and dorsal wall material were pale greenish blue and the caecae and gizzard had faint lavender tinges. After half an hour was seen crop, salivary glands, dorsal wall material, fat bodies, caecae, and ventral nerve cord; after two days was seen fat bodies and dorsal wall material only; but three days had fat bodies, dorsal wall material, salivary glands, and large intestine (posterior end).

COTTON BLUE.

In this stain one day was the best for all results. Loose fluid stain was present in the body cavity. The gizzard was pale blue as was also the salivary glands and the crop (here dark blue streaks present). The fat bodies were blue (at the injection point), as also the caecae and small intestine. The heart was deep blue and the dorsal wall material blue tinged. In half an hour the heart, gizzard, dorsal wall material, and thorax muscles were seen; in two the gizzard, salivary glands, crop, caecae, few malpighian tubules, heart, fat bodies, and intestines were seen; while on three days testing only the heart, salivary glands, caecae and fat bodies.

Fuchsin Basic.

The results were brief and best shown after half an hour. The salivary glands, crop, and gizzard (lower half) were light pink; the caecae (half of them) were pink; the malpighian tubules dark pink. In one day was seen half the malpighian tubules, salivary glands, and stomach; in two days only the heart and its outline; then on the third day trials the malpighian tubules, fat bodies (near the digestive tract) and stomach tracheae.

Crystal Violet.

Best results for structures and color were gained after one day. Light pink showed in the "veins" of the salivary glands, the stomach, and intestines. The fat bodies near the crop were light lavender, and the heart had a brown outline. Half hour results were on salivary glands, caecae, gizzard, and fat bodies; two days on stomach and dorsal aorta; three days on salivary glands, half the malpighian tubules, caecae, and intestines.

Pyronin.

More structures were shown after one day. There was a pink tinge on the crop and half the fat bodies. The caecae were pale pink; the dorsal wall material deep pink; a few malpighian tubules deep peach; and the heart deeply outlined in pink (out V-shaped along tracheae). Two days showed color variance, in the dorsal wall material, salivary glands, half the malpighian tubules, stomach, fat bodies, and crop; three days produced fat bodies, dorsal wall material, ovaries, one-third of the malpighian tubules, heart and its outline; in half an hour all the insides (scarlet).

Aldehyde Green.

Three days was best for structures and variability of color. The female reproductive organs and second and third leg femurs were light green; dark green showed on the fat bodies, dorsal wall material, and heart. Blue-green, light for the thorax muscles and dark for the malpighian tubules showed well. The anterior end of the crop was black. The fat bodies were deteriorated; this condition showed also in one and two-day results. Half hour results were caecae, malpighian tubules, three-fourths of the fat bodies, digestive tract, heart, dorsal wall material, and salivary glands; one day were malpighian tubules, caecae, digestive tract, dorsal wall material, femurs, heart and thorax muscles; two days were digestive tract, malpighian tubules, dorsal wall material, femurs, thorax muscles, and heart.

Borax Carmine.

Half hour results indicated the most structures. Scarlet accounted for the dorsal wall material (rosy shade), gizzard, intestines, caecae; fat bodies, salivary glands, and heart went from rose to pink to dull red. Color variance was obtained with three days on heart, posterior end of crop, dorsal wall material and thorax muscles, caecae, and gizzard; one day showed leg muscles, thorax muscles, gizzard to end of the digestive tract, heart; two days showed digestive tract (gizzard on), heart, thorax muscles, and tracheae.

Acid Fuchsin.

For structures one day was best for timing. The posterior end of the crop and the caecae were wine colored, and the heart and its outline was very deep wine. The dorsal wall material was pink; half the malpighian tubules dull pink. Tinges, pink on thorax muscles and scarlet on the intestines, were also present. Color changes predominated in three days work on thorax muscles, fat bodies, dorsal wall material, heart, intestines, salivary glands; half an hour resulted in fat bodies, heart, salivary glands, dorsal wall material, digestive tract, crop, and two-thirds of the malpighian tubules; two days resulted in fat bodies, digestive tract, dorsal wall material, gizzard and salivary glands.

Lack Good Results

Orange I.

One day testing proved best for number of structures shown and color variation. The caecae and stomach were reddish; the salivary glands slightly brown; and the thorax muscles red-brown. After half an hour run these showed up, i.e., malpighian tubules, digestive tract, and heart outline; two days, only the heart (tinged); three days, the caecae and traces on dorsal wall material.

Aurentia.

The best structure and color results were found after one day. Here the caecae and small intestines were reddish; the dorsal wall material and fat bodies had an orange-brown tint; the salivary glands were yellow as was the upper half of the crop (lower half, brown). Half an hour produced fat bodies, dorsal wall material, salivary glands, and caecae; two days produced fat bodies, dorsal wall material, salivary glands, thorax muscles, and caecae; three days produced caecae, small intestine, fat bodies, salivary glands, and heart outline.

Thionin.

One day results showed more structures and color The large intestine was purple speckled; the fat bodies were dark blue at the injection point; the tracheae a faint lavender (near the heart). Half an hour had only thorax muscles; two days no results; three days had digestive tract, caecae.

Alizarine Green G.

Half hour timing was best for both number of structures and variation of color. Light green appeared in the salivary glands, dorsal wall material (traces), and fat bodies (near injection point); the crop was dull green. One day had only malpighian tubules and heart outline; two days only malpighian tubules; three days showed salivary glands, malpighian tubules, and heart outline.

Orange G.

More structures and color variance appeared after half an hour. The caecae and stomach were orange; the thorax muscles with an orange-brown tint, and the dorsal wall material brown-tinge. One day lacked color only in fat bodies and malpighian tubules; two days had fat bodies, dorsal wall material, heart, stomach and hind gut; three days had heart, intestines, caecae, and dorsal wall material.

Phloxine.

One day's work proved best for coloration and structure showing Variations of pink dominated; from bright pink of the malpighian tubules and fat bodies (half of them); the pink of the salivary glands and caecae; to the pink outline of the heart. All the viscera were a rosy pink. Three days produced results on malpighian tubules, digestive tract, caecae, fat bodies, and heart.

Quinoline Yellow.

In this stain the half hour group was best for number of structures shown. The fat bodies and dorsal wall material were yellow, while the digestive tract showed an even clearer, bright yellow. The thorax muscles and salivary glands were light orange. For color variations two days was best as on fat bodies, dorsal wall material, caecae, and heart; one day had fat bodies, dorsal wall material, heart, caecae, and digestive tract; three days had fat bodies, dorsal wall material, heart, and digestive tract.

Bismarck Brown.

With this stain three days proved the optimum with color and structures. The caecae and small intestine were red-brown and the heart had a red-brown tinge. Along the tracheae the dorsal wall material was brown tinged (in the

abdomen). The fat bodies were brownish pink at the point of injection. Half an hour had tinged fat bodies; two days, fat bodies, dorsal wall material, and tracheae; one day, fat bodies, caecae.

METHYLENE BLUE.

Here one day results were best for number of structures shown. Pale blue showed on the fat bodies and salivary glands while the ovaries had a pale blue tinge as the nerve cord (between the ganglia). The thorax muscles were deep blue as was the heart outline and the caecae tips. The crop showed blue (lower half); the gizzard a purple tinge. Two days showed the most color changes as on intestines, malpighian tubules (few), heart outline, tracheae, salivary glands, caecae, gizzard, and fat bodies; half an hour showed thorax muscles, crop, nerve cord, heart, half the malpighian tubules, ovaries, salivary glands, fat bodies, and gizzard; three days showed crop, gizzard, and fat bodies.

EOSIN Y.

Half hour testing was best for structure number and color. The color went from red of caecae (fluid filled), bright pink malpighian tubules, orange pink salivary glands, salmon pink fat bodies, to orange outlined heart and pink tinged digestive tract and testes. For one and two days all the insides were colored; for three days, only the caecae, dorsal wall material, half the fat bodies, some malpighian tubules.

MAGENTA ROTH.

Extent of coloration and variance showed up in half an hour. The malpighian tubules were scarlet, the fat bodies rosy scarlet, dorsal wall material bright pink, thorax muscles pink; and the caecae were deep wine in color. One day results produced salivary glands, dorsal wall material, and fat bodies; two days, intestines and caecae; the same occurred for three days.

AURAMINE O.

After two days more structures appeared stained. Bright yellow accounted for the crop, malpighian tubules, and female reproductive organs. In the thorax region the heart was deep yellow, while the fat bodies were a creamy yellow and the dorsal wall material slightly yellow tinged. After half an hour all the insides were bright yellow; one day followed suit; three days varied some on caecae, fat bodies, salivary glands, and heart.

RHODAMINE 6G.

Here two days proved best for structure staining and color change. The dorsal wall material and fat bodies were pink and the digestive tract had a slight pink tinge. Salmon accounted for the thorax muscles and ovaries with the malpighian tubules and caecae being lavender. Half hour testing showed fat bodies, malpighian tubules, caecae, dorsal wall material, salivary glands, and digestive tract; one day colored all except tracheae; three days, the intestines, fat bodies, dorsal wall material.

ORANGE II.

After half an hour more structures were shown. The intestines, caecae, malpighian tubules were bright orange; the dorsal wall material, and thorax muscles light orange. The fat bodies and salivary glands had a light orange tinge while the heart had a dark orange outline. The greatest color variation was shown after three days, this on intestines, gizzard, crop, ovaries, and heart; one day showed on malpighian tubules, thorax muscles, femurs, digestive tract, dorsal wall material, and heart; two days showed on heart, malpighian tubules, crop, caecae, and thorax muscles.

WATER BLUE.

Three days presented the best color picture on the greatest number of structures. The caecae and gizzard were blue; the dorsal wall material and femurs a light blue; and thorax muscles were deep blue. The heart had a blue outline (out V-shaped along tracheae). The malpighian tubules were greenish blue. Half an hour showed dorsal wall material, a few malpighian tubules, crop, and caecae; one day showed at least tinges of color on all viscera; two days resulted in heart outline, caecae, gizzard, and ovaries

INDIGO CARMINE.

More structures were shown after half an hour. Most of the malpighian tubules and the crop were deep blue. The intestines and dorsal wall material were light blue as was the covering of the heart. A few fat bodies were blue tinged. After two days the range of color covered the greatest area, this on half the malpighian tubules, caecae, salivary glands, heart outline and femurs; one day showed one-third of the malpighian tubules, caecae, fat material; heart and malpighian tubules succeeded on three days.

ORCEIN.

In this case one day results proved best for all counts though evidence was meager. The caecae were a very faint pink; the small intestine lavender; and the edges of the heart were yellow tinged. Half an hour showed only the gizzard; two days, the intestines and caecae; three days showed heart outline and few malpighian tubules.

INCOMPLETES

METHYLENE GREEN.

Half hour testing proved best from the standpoint of number of structures shown and color variation. The salivary glands were pale green; the heart was outlined through the thorax region with green. One day showed the malpighian tubules (half), and ovaries (bleached).

MALACHITE GREEN

Only half hour testing gave results. The salivary glands, caecae and thorax muscles were dark blue; the malpighian tubules and heart were dark green while half the fat bodies were brilliant green. Femurs showed green and tracheae had a narrow blue outline.

PHLOXIN RED.

This also had only half hour data. The dorsal wall material and fat bodies were rosy scarlet; the treacheae had a scarlet tinge; the malpighian tubules were bright red.

NILE BLUE SULPHATE.

Here one day testing proved best for both numbers of structures shown and color variance. The salivary glands, caecae, gizzard, and small intestine were light blue; the dorsal wall material and crop were deep blue; the femurs and malpighian tubules were green. The fat bodies went from deep purple to yellow-green while the heart was violet. Half an hour showed femurs, thorax muscles, digestive tract, fat bodies, dorsal wall material, salivary glands, heart, caecae, and malpighian tubules.

JANUS GREEN B.

Half hour results were best on structure count and color. Deep scarlet showed on the crop and dorsal wall material and combined with blue shades in the fat dies. The malpighian tubules were deep blue as also the caecae; the heart was

more a navy blue; the thorax muscles were blue tinged. Gizzard and salivary glands were lavender. One day results were femurs, thorax muscles, heart, malpighian tubules, dorsal wall material, salivary glands, crop, and fat bodies.

ERYTHROSIN BLUISH.

The half hour work was best in structure and coloration counts. The gizzard was true pink and the ovaries deep pink tinged and a slight pink tinge on the digestive tract. The fat bodies varied from deep to light rose; the salivary glands a deep rose. The caecae were scarlet and the malpighian tubules orange-red. One day presented caecae, heart, thorax muscles, dorsal wall material, malpighian tubules, salivary glands, and fat bodies.

VITAL RED HR.

One day information proved best for structure and color showings. Brilliant scarlet was on fat bodies, gizzard, caecae, malpighian tubules; a duller scarlet for thorax muscles, dorsal wall material, and femurs The tracheae and salivary glands were pink, while the heart was dark pink with flakes of scarlet lying over it. The intestines had a reddish tinge. Half an hour produced fat bodies, heart, and most of the other viscera.

PO. COCHINEAL.

Half an hour was best with pink tinged small intestine (near the injection point) and dorsal wall material. One day had scattered dull green spots on salivary glands and fat bodies.

RECOMMENDED STAINS FOR PARTICULAR TISSUES

1) Heart—Toluidin Blue (½ hour); Trypan Blue (1, 3 days).
2) Tracheae—Fuchsin Basic (3 days); Borax Carmine (2 days).
3) Ventral Nerve Cord—Azur I (½ hour).
4) Gizzard—Acid Fuchsin (2 days); Azur II (2 days).
5) Caecae—Aldehyde Green (1 day); Acid Fuchsin (1 day).
6) Salivary Glands—Brilliant Cresyl Blue (½ hour, 2 days); Trypan Blue (½ hour).
7) Crop—Bordeaux Red (3 days); Blue de Lyon O (1 day).
8) Fat Bodies—Methyl Violet B (3 days); Azur II (½ hour, 2 days).
9) Thorax Muscles—Safranine O (2 days); Toluidin Blue (1, 2 days).
10) Malpighian Tubules—Azur II (2 days); Light Green SF Yellowish (½ hour, 1 day).
11) Dorsal Wall Material—Toluidin Blue (2 days); Aniline Blue (½ hour, 1 day).
12) Digestive Tract—Congo Red (½ hour); Aldehyde Green (½ hour).
13) Hind Gut—Azur II (3 days); Brilliant Cresyl Blue (½ hour).
14) Ovaries—Trypan Blue (½ hour); Aldehyde Green (3 days).

STAIN MANUFACTURERS

Coleman & Bell Co.	Norwood, Ohio
Dr. G. Grubler & Co	Leipzig
National Aniline & Chemical Co., Inc	New York, N. Y.

LITERATURE

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MONOSTROMA WITTROCKII IN OHIO[1]

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On July 15, 1941, the Ichthyology class from the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio, brought to the Laboratory a large collection of ***Monostroma*** which they had secured in the Portage River Although it was immediately identified as a species of this genus it was almost unbelievable that this genus could occur in a freshwater stream so far from its usual marine or brackish water habitat.

During the summer of 1942 the writer visited the area with one of the original collectors but was unsuccessful in finding it although the stream was examined for several hundred yards in either direction.

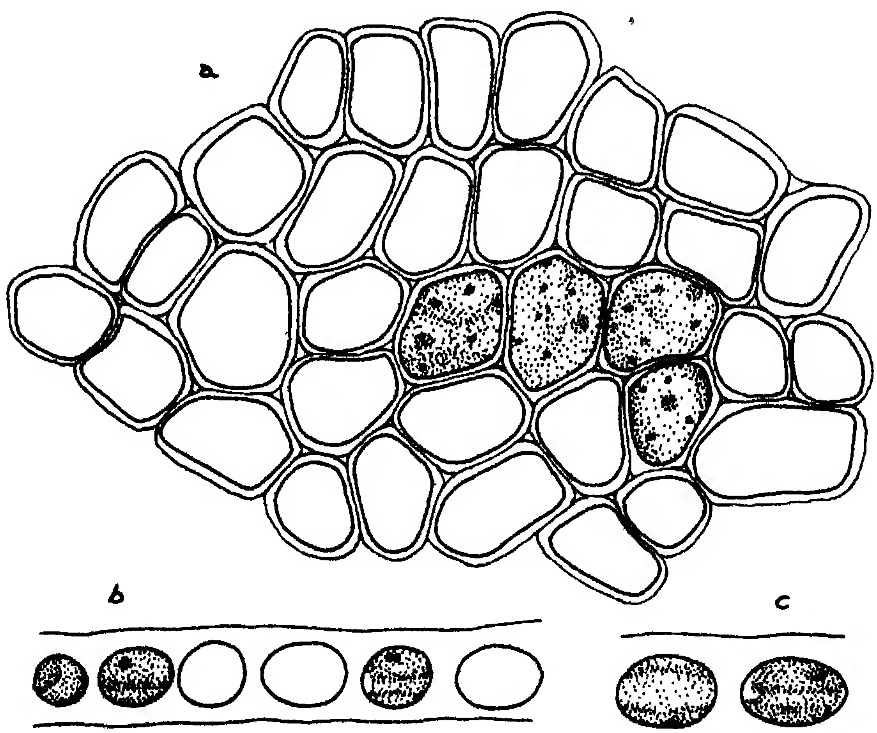

Fig. 1. ***Monostroma Wittrockii*** Bornet. (a) Cells in face view. (b and c) Cells in section from two parts of the same thallus.

The original discovery was made in that area of the Portage River which lies in Sec. 9, southern Harris Twp., Ottawa County, Ohio. This is about 16.5 miles west of Port Clinton and approximately 5 miles west and a little south of the village of Oak Harbor. The stream at that time had about 50% well defined

[1]Paper from the Department of Botany, The Ohio State University, No. 484.

riffles and the remainder pools with little or no current. The bottom was chiefly glacial gravel, boulders and silt. Some field and sewage pollution existed.[2] The algae, some of which was attached to sedges and unidentified weed stems, formed floating, gelatinous masses along the margin of a silted-bottom pool. The abundance (8 quarts in the collection) as well as the attached thalli attest to the fact that it was well established and that it was not the chance discovery of a few fragmentary scraps discarded accidentally or by design. One can only speculate on the events leading to its introduction into Ohio. Birds may have been responsible, but this seems very unlikely. Another possibility which seems more plausible, is that fragments or reproductive cells were brought in with sea food or with material used in packing such food. The fact that the river flowed through a quantity of trash and kitchen refuse discarded from a home about fifty yards above the area, lends credence to this theory. Its failure to reappear during the summer of 1942 may be due to the scouring of stream bottom and margins by spring floods.

Monostroma Wittrockii Bornet is listed by Taylor (1937) from a salt marsh in southern Massachusetts. In the young form it is attached and saccate. With age it splits more or less into a broad, irregularly lobed blade which is very fragile and breaks loose from its attachment. The blades in the Ohio material reached a length of about 12 cm. and were a pale green color and quite slippery. In parts of the thallus the cells may show a definite grouping into 2 and 4. The cells are angular, with fairly thick walls, and a diameter of 9–18μ. Cells in section are rounded to oval, 9–12 x 11–15μ. Thallus about 16–21μ thick.

The writer expresses his appreciation to Dr. E. N. Transeau of this Department and to Dr. G. W. Prescott, Albion College, Albion, Michigan, for their advice.

CITATION

Taylor Wm. Randolph. 1937. Marine Algae of the Northeastern Coast of North America. Univ. Mich. Studies, Sci. Ser. Vol. 13, pp. 1–427. Pl. 1–60.

[2]Data pertaining to geographical location and stream conditions supplied by Mr. Milton B. Trautman, The Franz Theodore Stone Laboratory, Put-in-Bay, Ohio.

Insects of the Pacific World

This volume is another in the Pacific World Series. As indicated by the title it covers the insects inhabiting the large and small islands of the Pacific Ocean areas. However, one chapter is devoted to the class Arachnida, with major emphasis on spiders, mites, ticks and scorpions.

The subject matter covered is as follows: Insects and their Relatives; True Flies—Order Diptera; Bees, Wasps and Ants—Order Hymenoptera; Butterflies, Moths and Skippers—Order Lepidoptera; Beetles—Order Coleoptera; True Bugs—Order Hemiptera; Clear-wing Bugs—Order Homoptera; Dragonflies and Damsel Flies—Order Odonata; Nerve Winged Insects—Neuropteroids; Order Orthoptera; Miscellaneous Orders; Arachnids and allies; Insects and Disease; Collecting, Preserving and Shipping Insects.

The arrangement of topics is in reverse to that commonly followed in presenting information concerning insects from the classification viewpoint. Each chapter consists of a brief discussion of the characteristics, habits and distribution of major species of each family of the Orders covered.

The book is illustrated by 97 figures and 8 plates. The figures are zinc etchings of adult insects and the plates are half-tones of adult Lepidoptera and Odonata.

The information is authentic and with the style of writing the book should be of considerable interest to the laymen as well as the professional entomologists.—*Ralph H. Davidson.*

Insects of the Pacific World, by C. H. Curran. 317 pages, 105 illustrations. Macmillan Company, New York. 1945. $3.75.

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SYMPOSIUM ON THE RECENT ADVANCES IN THE MEDICAL SCIENCE

Papers delivered before the Medical Sciences Section of The Ohio Academy of Science, at The Ohio State University, May 3, 1946.

ADVANCES IN PUBLIC HEALTH

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Public health has passed its adolescent stage and is emerging into maturity as a positive science. The scientific advancements of the past quarter century have brought with them a phase of public health consciousness on the part of the medical profession as well as the general public, with the result that tools have been developed whereby the health of the people as a whole has been improved. Withal, we are only beginning the battle against disease and the next few years will see many more advancements.

New case finding techniques in tuberculosis are being expanded, mainly in the field of mass x-ray procedures. With the use of microphotofluorographic equipment, large numbers of persons can be screened effectively and at relatively low cost. The follow-up of suspects and cases includes the examination of contacts, along with education in prevention and treatment. Increasing emphasis is being placed on the finding of early cases in a wholehearted effort to cure and rehabilitate, so that patients may become self-supporting and useful members of society.

Research goes on in the use of aluminum in the prevention and treatment of silicosis, where evidence, available to date, indicates aluminum therapy is of therapeutic significance. It is recommended, however, that the general application of aluminum therapy in industry be delayed until adequately and impartially controlled clinical observation demonstrates a practicable effectiveness. In the meantime, there should be no slackening in the control measures that have been found to accomplish a reduction of the hazards of harmful dusts in industry.

During the past few years great strides have been made in the control of communicable diseases. To name but a few . . . , a significantly effective influenza vaccine has been developed, and diphtheria toxoid has been combined successfully with tetanus and whooping cough immunizing agents. It is noteworthy that, because of complete immunization by the Army and Navy, tetanus was extremely rare in the armed forces during the recent conflict. Recent developments have given us an immune globulin for the prophylaxis and treatment of measles which may have far-reaching possibilities in this, as well as other fields in pediatrics. Research goes on with penicillin, its usefulness already having been established in reducing the period of communicability of certain of the more common infections, and in reducing the hazards of complications.

Penicillin also permits the safe and effective rapid treatment of syphilis and gonorrhea, allowing more emphasis to be placed by public health agencies on case finding. The main value of the short-term therapy of syphilis is the reduction in the proportion of lapses from treatment, so frequent in long-term standard therapy. However, in the manufacture of penicillin for commercial use, certain refinements have lowered its curative value for syphilis. Knowing that factors F and G are essential for the successful treatment of this disease, and that factor K is the least effective, methods have been developed during the past year to inhibit the formation of the K factor. At the present time, a considerable amount of commercial penicillin containing an abundance of the K factor and deficient in F and G is on the market, thus necessitating relatively larger doses of the drug to effect cure.

The diagnosis of syphilis is primarily a laboratory procedure and the recently developed cardiolipin antigen can be set at a stable sensitivity level, while increasing specificity, giving cause for hope of enhancing the reliability of serodiagnostic methods. Cardiolipin, however, is still definitely experimental, but, if proven, may result in a complete overhaul in the field of syphilis serology.

The extent of the toxicity to human beings of D.D.T. (dichloro-diphenyl-trichloroethane) is not known, but it has been found that it can be used in the control of insects with little danger to the user if reasonable precautions are observed. Perhaps in this country it will find its greatest use in the control of malaria. At the present time, the U. S. Public Health Service is engaged in an anophelene mosquito control program in the endemic areas of the southern states, putting to use practices found effective by our armed forces. D.D.T. is also being used effectively in the control of the vectors typhus and yellow fever. It must be remembered, however, that though D.D.T. may prove to be a boon to humanity, it must not be regarded as a substitute for sanitation.

In the field of dental health, the discovery that the topical application of a two per cent solution of fluorine reduces the incidence of dental caries by approximately fifty per cent, offers great possibilities. Perhaps we may be justified in assuming that in the not too distant future, caries will be a minor instead of a major problem in oral health.

One of the important causes of death in childhood is rheumatic fever, and although it is not known as yet, with certainty, whether rheumatic fever programs are preventing illness or prolonging lives, substitution of good management for the neglect or over protection which frequently characterizes the handling of these children, is enough to make these programs worthwhile. Realizing the need for better and more widely available consultative services for rheumatic fever, as well as coordinated services for the care of patients, health departments are encouraging the development of such facilities. In some instances, clinics are being organized independently by local medical associations and hospital staffs, working cooperatively with local or state health departments in case finding, follow-up and education.

The outlook for the control of cancer is definitely improving. There is growing evidence that cancer patients are seeking medical care earlier in the course of their disease, enhancing their chances of survival. This trend is due in most part to public education. Even in the present state of our knowledge, many lives could be saved annually by earlier diagnosis and with the institution of appropriate treatment. The ultimate answer, however, lies in the laboratory.

Today, public health has developed to the point where it has become apparent that many diseases cannot be controlled without full citizen understanding and participation, and therefore health education is coming to be universally accepted as an essential part of every public health program. To stimulate public action and individual participation, well planned and coordinated programs of education are required. Three major methods are employed in health education, namely:

as a part of teaching in the schools and colleges, health information for the general public; and health teaching by those who are actually engaged in giving medical care to the sick. This latter is one of the great responsibilities and privileges of the practitioner of medicine

It is generally accepted that some method is needed for distributing the risks in sickness and the costs of medical care, so that the population as a whole can gain access to medical services as needed. Insurance and taxation are the two methods of distributing costs. Both are employed in this country, but as yet only for special groups of people or for particular types of care, usually hospitalization. Plans for insurance are faulty in many respects in that they do not offer comprehensive medical care, provide for no prevention or control of disease, are not really plans for medical service but for financing general hospitalization and surgery. Because of variations in the types of services offered by the 219 plans for prepaid hospitalization in this country, it is impossible to compute any arithmetic totals of service furnished by them.

The year 1945 was revolutionary inasmuch as it witnessed the publication of two books which bared the shortcomings of public health facilities as provided by official and voluntary health agencies. Reference is made to the report of the Commonwealth Fund by Haven Emerson, M.D , entitled "Local Health Units for the Nation," which reviews the organization and management of the health departments of each of the 48 states and gives recommendations for improvement in service; and the Gunn-Platt report, "Voluntary Health Agencies—An Interpretive Study," made under the auspices of the National Health Council. This latter report is a critical review of the services available through health agencies throughout the nation which are dependent upon voluntary contributions for survival. Both reports are serving a useful purpose inasmuch as they expose the weaknesses of existing health services organized entirely for the benefit of the people, and dependent entirely upon the people for support, whether supported through taxation or by voluntary contribution.

The contemporary health services offered in our nation, supply only about two-thirds of the population with adequate full-time local health protection, while approximately 40 million persons are excluded for one reason or another. The question which faces all those interested or participating in the provision of public health services seems to be--can we move on into the realm of attaniable possibilities and meet the needs and wishes of the people to the achievement of still higher levels of human health and welfare?

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UROLOGY

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Advancements in the field of urology have been made (1) the treatment of urinary calculi, (2) carcinoma of the bladder, and (3) carcinoma of the prostate. The treatment of urinary infection with penicillin and streptomycin has specific applications in urology, but they also have many general applications and therefore will not be discussed. There have been many technical improvements in the older methods of therapy and diagnosis which are unsuitable for discussion.

The cause of urinary calculi has been studied from the standpoint of calcium metabolism and endocrines. The most specific advancement in the cause of stone formation has been made by Albright (1). In a study of 23 cases of hyperparathyroidism he found 15 patients to harbor renal calculi and three other patients had renal leisons due to calcium deposits in the renal tubules. Hyper-secretion of the parathyroids results in increased calcium and decreased phosphorus in the blood. It is an excellent example of what may happen when a kidney has to deal with a blood stream which is laden with calcium. Bone diseases and immobilization of the patient may result in increased urinary calcium which is derived from decalcification of the bone. The increased excretion of uric acid, oxalates, and the presence of cystin in the urine are other examples of hyper-excretion of a specific salt which may result in stone formation.

There is a great deal of difference of opinion as to the frequency with which hyperparathyroidism occurs as an etiological factor in the formation of renal calculi This phase of the disease has been stressed by Albright et al. from the Mass. General Hospital. From 1930 to 1937 in a study of 36 cases of hyperthyroidism, Chute (2) found calculi formation in 83% of them and the disease to be bilateral in 53%. Braasch (3) at the Mayo Clinic found but two cases of proved hyperparathyroidism in 1,206 patients suffering from calculus disease. Higgins (4) at the Cleveland Clinic found the disease in only one-tenth of one per cent of stone patients.

Regardless of the wide difference of opinion as to the frequency of hyperparathyroidism in stone formation, one fact seems to stand out and that is that where hypercalcinuria occurs stone formation may result. This is substantiated by Flocks (5) who found that 66% of stone cases showed increased urinary calcium and in a great number of them none of the causes of excess calcium excretion was discoverable.

The above facts have stressed the etiology of certain varieties of stone formation due to excess of calcium excretion by the kidney. Advantage of this knowledge has been taken in the prevention and treatment of stone formation. It has long been known that the pH of the urine is a factor in the type of stone formation which will occur. Thus with a pH of 5 a uric acid stone should form; whereas with a pH of 8 calcium carbonate and phosphatic stones occur. It would seem that with a reversal of the pH of the urine, in the examples cited above, it should be of aid in the dissolution and prevention of these stones. Within certain limits this is true.

In those calcium and phosphatic stones in which hypercalcinuria plays a part, the administration of acidifing drugs and the so-called "acid ash diet" have been shown by Albright and Flocks to defeat their purpose, in that their administration results in increased absorption of calcium from the tissues and increased excretion of calcium by the kidney. This is especially so where stone formation is taking place in the presence of urea splitting organisms, where it is impossible to render the urine acid. These procedures are definitely contraindicated, because, bringing

more calcium to the infection means more rapid stone formation. It is evident that the purpose of this type of medication is to decrease the precipitation of calcium and phosphatic salts at the kidney level and thereby prevent stone formation.

Shorr (6) . . . believed that the less calcium and phosphates the kidney had to dispose of, would also lessen the possibilities of stone formation. He lowered the calcium and increased the citric acid content of the urine by the use of estrogens. Estrogens increase the excretion of citric acid and the citrates combine with calcium to form a soluble calcium-citrate complex instead of an insoluble calcium phosphate. He diverted the excretion of phosphate from the kidney to the intestinal tract by the use of aluminum hydroxide gel. By the use of both agencies he was able to prevent the precipitation of the relatively insoluble electrolytes of calcium and phosphorus, which participate in the formation of calcium and phosphate stones. This reaction takes place regardless of diet or infection of the kidney.

The doubtful efficacy and limitations of dietary and medicinal agents to dissolve or prevent stone formation led Suby and Albright (7) to investigate the effects of citric acid sodium citrate solution in the dissolution of stone. They found this solution would destroy the mucous membrane of the bladder in a short time, but they also found that by the addition of magnesium oxide, they lost none of the dissolving properties of the citric acid solution and the irritating effects of it on the bladder mucuosa were neutralized. This resulted in a buffered citric acid solution which is known as G solution and is particularly efficacious in dissolving loosely constructed calcium and phosphatic stones by means of direct application of the solution to the stone.

Another interesting if not so practical application of medicinal agents in the dissolution of urinary incrustations is furnished from the fact that in the waters of the Amazon Basin is a little fish (Candiru) which penetrates the urethas of men and women bathers particularly if they should pass urine when in the water. The great speed of this little fish allows it to enter the urethra and bladder as the urine is being expelled. Here it attaches itself to the mucuosa of the bladder and produces a very painful lesion. The natives have found that by making a brew of the Buitach Apple (*Genipa americana*) which grows in the Amazon Basin and when drunk very hot has the property of dissolving the skeleton of the fish. This has resulted in an analysis of the brew and its application for the dissolution of bladder incrustations due to calcium salts. A synthetic formula of this brew has been composed and used with success by Dr. Lin (8) in cases of encrusted bladder. The formula is administered by means of rectal injections.

In 1941 Huggins (9) advocated bilateral orchidectomy for carcinoma of the prostate and later introduced stilbestrol in the treatment of the same condition. Both procedures have proved to be immensely valuable and represent progress in the treatment of carcinoma. During the last five years urologists have tried to determine the efficacy of each procedure. After the diagnosis of carcinoma of the prostate has been established, the following questions always arise: (1) When should we do orchidectomy; as soon as the disease is diagnosed or should it be reserved for patients with marked metastases, pain and other symptoms? (2) Should stilbestrol be used first to be followed by orchidectomy late in the disease? (3) Should orchidectomy be performed first followed by the use of stilbestrol or (4) should one method be used to the exclusion of the other? During the last five years physicians have had enough experience with both procedures to render opinions and their value. To determine the trend of clinical opinion, Meads (10) recently sent out 100 questionnaires to urologists concerning the above questions. Out of 78 replies, 70 urologists favored orchidectomy. . . . Of these 23 insisted the operation should be done early and 47 were convinced that it should be performed late, that is, when signs of metastases had developed as evidenced by pain, x-ray findings and rise in serum acid phosphatase.

Huggins wrote: "We still believe that bilateral orchidectomy is considerably superior to estrogenic treatment, feeling that the remission is greater and more prolonged. Further, we do not give patients who have had orchidectomy estogen except occasionally for a short period of relieve hot flashes. Our preference for orchidectomy over estrogenic treatment is not one of caprice, I believe, since we had the pleasure of introducing both methods of treatment for this disease. We proceed with the removal of the testes as soon as the diagnosis has been made, except that an occasional patient is encountered with a lesion small enough for radical perineal prostatectomy. Incidentally, in Chicago this happens once in a blue moon."

Forty-seven urologists believed that stilbestrol should be administered first and bilateral orchidectomy delayed until late in the treatment of carcinoma of the prostate. Young believes that if it is a carcinoma entirely confined to the prostate, radical operation may cure; if it is too extensive for radical operation, stilbestrol in doses of five milligrams daily. When stilbestrol fails, orchidectomy is certainly indicated. Braasch (3) says we reserve orchidectomy until metastases and severe pain develops. Nesbitt reserves orchidectomy for patients who show evidence of an advanced disease.

Mead's paper shows that about one-third of the urologists perform bilateral orchidectomy for carcinoma of the prostate as soon as the diagnosis is made, and that two-thirds delay this operation until metastases can be recognized. While this paper represents nothing new, it does summarize the trend in application of a very valuable procedure in prostate carcinoma.

A new way to apply x-ray therapy to bladder tumors has been advanced by Rose (11). He believes that carcinoma of the bladder of the invasive type is sufficiently similar to skin cancer and if direct x-ray exposure could be successfully applied in the bladder as in the case of skin cancer, we might hope to cure certain carcinomas of the bladder by this method. To apply x-ray in this manner he opens the bladder widely to expose the tumor and by means of a sterile lead shield the x-ray is applied directly through the wound. He anticipates favorable results in about 25% of the cases and believes the procedure is another aid to be considered in bladder malignancies and states that his ten years results are very promising.

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RECENT ADVANCES IN OPHTHALMOLOGY

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Prior to the present war, research in the field of plastics was advancing into new fields. New varieties of plastics and new uses for them have been found. Thus in the field of ophthalmology we have parts of optical and surgical instruments being made of plastic. There is a transparent retractor of plastic, useful in the retinal detachment operation. Sets of prisms used for measuring muscle imbalance are available but have the objectional feature of being more easily scratched if subjected to hard usage. We have heard much of the prosthesis or "glass eye" made of plastic. It is true that a much better prosthesis can be made of plastic than those we have had before. A mold or pattern can be made of the socket, a plastic casting can be made from this mold which will fit that patient It is non-breakable and can be repolished when it becomes rough, whereas a prosthesis made of glass must be replaced after a few years because it becomes discolored and rough. It has long been recognized that even the best fitted prosthesis has its limitations. Since it fits by contact under the lids, its motion is limited. This is true particularly in the horizontal plane where its movement is limited by the bony orbit. The correction of this obvious defect has baffled eye surgeons for a long time. At present there are several operations being developed to overcome this objection. One such operation may be briefly described as follows. The enucleated eye is replaced by a complete plastic eye, the posterior half of which is covered with a tantalium wire mesh. Small tantalium plates are sutured to the four recti muscles. These plates are then properly attached to the prosthesis. Such technique permits complete freedom of motion of the prosthesis. As is usually the case certain technical improvements must still be made before this operation can replace the older method. Contact lenses are now being made of plastic, therefore less dangerous to the wearer than those made of glass. Contact lenses of glass are not new, having been originally devised for persons suffering from conical cornea. It might be mentioned here that contact lenses have very definite indications for their use and in no sense are to be regarded as a substitute for glasses.

The coating of optical lenses with a substance to eliminate annoying reflections is making progress. When first developed it was discovered that the coating could be wiped or washed off when cleaning the lens. It is believed that this objectionable feature is not yet ready for the market in any quantity.

A simple device was produced to assist in localizing intraocular foreign bodies It consisted of a plastic contact lens with four equidistant metalic dots in it so arranged that these dots were very close to, or in contact with the limbus. Military hospitals where the removal of intraocular foreign bodies was being done found that the information obtained by this localizer was often very valuable.

Improvement has been made in the operation for transplantation of the cornea More eye surgeons are performing the operation, and as instruments become available we can expect this relatively new surgical procedure to become more common. An eye bank has been established in New York City to which donors eyes may be sent. It has been found that the cornea of such eyes sent to the eye bank are suitable for transplantation 36 to 48 hours after leaving the donor. Enucleated eyes with normal cornea should not be wasted. There is a waiting list of those who need them.

Experience gained in the war has given us a much better understanding of the indications, limitations and use of penicillin. Detailed information is now available in current literature. One example may be cited. In Ohio it has halved the taxpayers cost for the care of gonorrheal conjunctivitis in the indigent, and concurrently visual loss from the same cause has been greatly reduced.

RECENT ADVANCES IN PEDIATRICS

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The time allotted could be spent entirely in merely cataloguing the many recent advances in Pediatrics. Instead of this, I would prefer to discuss in some detail two of the concepts which have grown to prominence recently which appear to be of fundamental importance.

CONGENITAL ANOMALIES FOLLOWING GERMAN MEASLES IN THE PREGNANT MOTHER

Until the past few years it has been generally accepted that congenital malformations result from defects in germ plasm existent prior to conception. A very significant advance in thinking concerning the etiology and prevention of such anomalies has followed the demonstration that maternal infection may also play a part in their origin. Following an epidemic of German Measles in Australia, Gregg (1) noted what seemed to him to be a veritable epidemic of babies born with eye and heart anomalies. Further study revealed that most of these particular babies had been born of mothers who had had rubella during their pregnancy. Swan (2), also in Australia, soon corroborated these observations and extended them to include pathologic reports of three such infants who died of intercurrent infections. At least five American authors have also found similar cases in their experience (3). To the present, these workers have reported 145 instances of various congenital anomalies in mothers with a history of rubella during pregnancy. In 77 of these, the anomalies were multiple. Mental deficiency was seen in 88 cases, cataracts in 112 cases, heart malformations in 83 cases, microphthalmos in 13 cases, and deaf mutism in 12 cases. It seems inconceivable that such a number of malformations should be brought to light in the few mothers that wait until pregnant to develop this childhood disease.

It is obvious that attention has been called to this relation because of the malformations rather than the maternal rubella. However, it is difficult to collect accurate statistics on the total number of mothers who have rubella during pregnancy and subsequently compare their offspring with a control series as to the incidence of anomalies. There might be considerable doubt concerning the validity of the above relationship if it were not for another observation too unique to be due to coincidence. With the exception of four cases, all the 145 mothers had their rubella before the fourth month of pregnancy. Swan reported observations on 49 cases of rubella in all stages of pregnancy of which 25 occurred before the third month. Every one of these infants was malformed. Four out of eight infants whose mothers had their disease in the third month were malformed, while beyond the third month, only two out of sixteen showed defects. This fact has led to speculation that the fetal infection which is assumed to occur must affect the fetus during a stage of critical development of the eye and heart structures for an anomaly to result.

These results have stimulated several investigators to explore the possibility of other maternal infectious diseases leaving deformed offsprings in their wake. This search has so far been rather fruitless since only two cases have been found in which the mother had mumps, and two in which she had influenza. Apparently German Measles is not as innocuous as was once thought. These observations and similar ones of his own have led Erickson to suggest mandatory abortion of any mother acquiring the disease in the first trimester of pregnancy.

CYSTIC FIBROSIS OF THE PANCREAS

Anderson (4), and Blackfan and May (5) independently in 1938 described a syndrome in infants resembling celiac disease in some respects which has come to

be known as cystic fibrosis of the pancreas. This is not a particularly rare disease, for we see four to six cases a year at Children's Hospital. Attention was directed to the condition by the observation that some children with celiac syndrome eventually recovered, while others suffered repeated and severe pulmonary infections which were invariably fatal. According to the concept developed by Farber, the condition is an hereditary one. Sometimes at birth and other times during the first year, the secretion of the pancreas becomes so thick and viscid as to effectively plug the secretory ducts and stop the flow of pancreatic juice. This deprives the bowel of pancreatic enzymes and leads to a fatty diarrhea. As the result of the plugging of the ducts, the acini become grossly dilated and cystic, and the pancreas undergoes fibrosis. This picture of pancreatic involvement is striking and constant. However, many other glands in the body may also undergo the same alteration in secretory power. The bronchial mucus glands are often involved, resulting in the secretion of a substance so thick and tenacious that it cannot be effectively removed from the bronchial tree. Infection with low grade pathogens from the pharynx (Staphylococcus aureus usually) then takes place following an upper respiratory infection. The pneumonia is characterized by marked emphysema from the air trapped behind the sticky plugs of mucus. Clinically, these patients are usually thought to have whooping cough at first, so violent are their attempts to clear their air passages. The salivary glands, lachrymal glands, Brunner's glands, and even the liver have in some cases been the site of the same unphysiologically thickened secretion.

The pancreatic deficiency causes a loss of excess fat and protein in the stool, so that these children may be quite malnourished though possessed of an exceptionally good appetite. Even more important is the aspect of pulmonary infection which, once it becomes established, is with rare exceptions fatal in the end.

The diagnosis is complicated by the insidiousness of the onset. In most of the cases, the true nature of the condition has been first found at autopsy. Recently, however, it has been recognized during life by suspecting the condition in any infant with so-called whooping cough, or chronic pneumonia, or repeated bronchitis whether or not the child also shows evidence of steatorrhea. Thus, clinically, although the disease is still called cystic fibrosis of the pancreas, most diagnoses during life are made by attention to the pulmonary symptoms.

The true nature of the condition is established by demonstrating the absence of the enzyme trypsin in the pancreatic juice. This is accomplished by sampling the contents of the duodenum in the fasting state by means of a Levine tube. Dilutions of the duodenal juice are then allowed to act on gelatine. If the gelatine is not liquified, it is taken as evidence of an absence of trypsin. The procedure is more difficult than it sounds since it is a long and arduous one, especially in a child who is dyspneic from his pulmonary involvement. Any contamination of the duodenal juice with stomach acid may invalidate the test, and sometimes it is practically impossible to enter the duodenum with the Levine tube.

Recently, West and Wilson have proposed an equally logical test based on the observation that these children cannot break down proteins sufficiently into their ultimate amino acid components. A test meal of casein or gelatine is given after a fasting determination of the blood amino acid content. Thereafter, in the manner of a glucose tolerance test, serial amino acid "levels" are taken. Normally the fasting value is close to 1 mg. %. In the normal infant this rises to 4 or 6 mg. % after a casein meal. In cystic fibrosis of the pancreas, there is no significant rise.

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SOME RECENT ADVANCES IN PHYSIOLOGICAL CHEMISTRY AND NUTRITION

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It is a most difficult task to attempt such a brief review of recent advances in physiological chemistry and nutrition. Last year (1945), even after a succession of war years, 8,137 abstracts on biochemical subjects appeared in *Chemical Abstracts* in the Sections on Biochemistry and Foods alone. Also, we have the further evidence of the tremendous activity in this field in the appearance each year of the *Annual Review of Biochemistry*, the most recent volume of which (for 1944) comprised 856 pages. Accordingly, the material presented here will be quite general and will be illustrative of trends of development over the past few years rather than an attempt to cover any field in detail.

The Carbohydrates.

The three most important polysaccharides in nature are cellulose, starch and glycogen. The structures of these compounds are similar in that they are made up of glucose units bound together between the 1-C of one glucose molecule and the 4-C in the next. The view that this 1–4-linkage is the one always elaborated by natural synthesis has been contradicted in recent years by the discovery of carbohydrates with 1–2-, 1–3-, and 1–6-linkages. Starch is believed to be a molecule made up of *repeating units*, each consisting of from 24 to 30 glucose molecules (1), and combined by cross linkages to form a molecule of about 200,000 molecular weight Most natural starches contain at least two components, designated as amylose and amylopectin. Thus, corn starch (2, 3) contains 10–20 per cent of amylose of unbranched chains of molecular weight 10,000 to 60,000 and 80–90 per cent of amylopectin with highly branched chains of 50,000–1,000,000 molecular weight. The most important polysaccharide in the human body is glycogen, the molecule of which is considered to be spherical in shape and to which a weight as high as 4,000,000 has been assigned (4). Such a molecule would contain nearly 23,000 glucose units.

The role of phosphoric acid in nearly all of the phases of carbohydrate metabolism has now been well established, beginning with the phosphorylation of absorption and ending with its various functions in the utilization of carbohydrates in the tissues. A most interesting achievement is that of Green and Cori (5) who isolated phosphorylase from rabbit muscle. One of the components of this enzyme is a crystalline euglobulin of molecular weight 400,000. This enzyme catalyses the formation of glycogen from glucose-1-PO_4, and presumably also the breakdown of glycogen. By studies with deuterium labelled compounds Stetten and Boxer (6) showed that 69 per cent of liver glycogen (in rats) was turned over daily but only 19 per cent of carcass glycogen. Labelled CO_2 has been shown to appear in both liver and heart muscle glycogens (7). The course of intermediary metabolism of carbohydrate, leading to its final oxidation, is still the subject of active research and rapidly changing views with practically no final answers to the problems raised. In this connection the Krebs tricarboxyllic acid cycle is most often mentioned (8).

The Fats and Oils and Other Lipids.

Methods for studying the glyceride structure of the fats and oils and of their component fatty acids are being continually improved. It is now possible to evaluate the fatty acids of these lipids with a high degree of accuracy, and in many

instances to discover new fatty acids, hitherto not believed to be present. Thus, a few years ago hexadecenoic acid was a rare compound in fat chemistry. Now, as a result of refinement in distillation and other procedures (9) it has been found in most animal fats examined, including human fat (10) and human milk fat (11), the latter containing 2.6 per cent of this acid.

The separation of fatty acid mixtures by low temperature crystallization from organic solvents (12) and the development of spectrophotometric procedures for the estimation of unsaturated acids with more than one double bond have proved to be important methods of study. Several reports have already noted the occurrence of fatty acids with conjugated unsaturation in naturally occurring lipids. The significance of these compounds in fat metabolism has not been studied.

More and more attention is being paid to the lipo-proteins (13). The lipid components of these compounds are usually not extractable from tissues without being previously diassociated from the proteins by hydrolysis (HCl), by extraction with methanol or ethanol, or by such a mild treatment as freezing at —25° (14), this last treatment having been shown to release the bound lipids of blood plasma.

An interesting development in fat metabolism is the view expressed by Frazer (15) that glycerides can be absorbed as such. Thus the classic concept of the necessity of complete digestion to fatty acids and glycerol preliminary to their absorption seems to be seriously questioned. Depancreatized dogs absorb up to 75 per cent of ingested fat (16). Other developments in fat metabolism have been due in no small part to the use of tagged molecules, especially the deuterium, used first by Schoenheimer and coworkers (17) Thus, the processes of desaturation of fatty acids, of interconversion of one fatty acid with another in the tissues, and of new functions of depot fat have been experimentally demonstrated. The fat depots seem to be one of the important destinations of dietary fatty acids, even when they are fed to a partly starved animal. Depot fat, long considered to be an inert storage material, has now assumed the role of a rapidly changing, functioning organ. In fact, the half-life periods of the fatty acids of various tissues have been actually determined (18, 19). Likewise, we are seeing rapid changes in the theories of fat utilization. The classic beta-oxidation theory is now scarcely recognizable, although it still accounts for a considerable part of the oxidation mechanism. The production of ketones is considered to be a normal process, largely resulting from recombination of the acetate residues or "active acetyls" produced by beta-oxidation. Incidentally it has been suggested that acetoacetate, or some other similar product of fat metabolism, enters the scheme of carbohydrate metabolism by conversion to oxaloacetic acid which is one of the compounds of the citric acid cycle (20). In this sense fat and carbohydrate metabolism merge into each other, and the fat does indeed burn in the flame of the carbohydrate, as we were teaching twenty years ago.

The Proteins.

Two recent volumes on "Recent Advances in Protein Chemistry" have reviewed progress in this field (13). All crystalline enzymes so far isolated have been found to be proteins. In the pituitary gland alone at least six hormones of a protein nature have been demonstrated and their properties described. In the later aspects of this work the Tiselius electrophorometer has been especially useful, as well as in extensive work on the patterns of the plasma proteins. The plasma proteins have been the subject of a most extraordinary series of fractionations by the Harvard group, headed by E. J. Cohn (21). From human plasma several simplified protein fractions have been prepared, studied, and adapted to specific uses in medicine. Thus, the gamma-globulins possess an antibody titer approximately ten times that of pooled plasma and can be used to confer passive immunity against measles, infectious hepatitis, and the like. Albumin of over 98 per cent purity is available in 25 per cent solution for use against shock and for many other purposes.

Incidentally, the albumins and globulins are heterogeneous in composition, and are usually associated with lipid and with glucosamine,—thus in fact being conjugate proteins. The viruses, which are found in the border zone between bacteria and non-living protein molecules, have been shown to be nucleoproteins of very high molecular weight and to possess the unique property of reproduction.

Study of protein metabolism with isotopic N^{15} has demonstrated the rapid interchange between dietary nitrogen and the nitrogen of the amino acids in the protein molecule of the living tissue; this isotope has also been employed in studying the intermediary metabolism of the individual amino acids. By this method, creatine has been shown to be derived from three sources, glycine, arginine and methionine, each of these amino acids contributing specific fragments to the creatine molecule.

Hydrolysates of complete proteins such as casein and lactalbumin are coming into use in medicine in the treatment of hypoproteinemia and other disorders; some of them are suitable for parenteral administration. According to the newer views the plasma proteins are in dynamic equilibrium with the proteins of the tissues. Theoretically, at least, the total protein nutrition of an individual can be adequately supported by administration of the plasma proteins.

General Trends in Nutrition.

The last ten years of research in nutrition have seen the field develop from a qualitative to a fairly quantitative science. Most of the better known vitamins have been identified chemically, many of them are prepared synthetically so that they are very inexpensive, and accurate methods for their quantitative estimation have become available. We now have accurate tables of analysis of the several vitamins, which suffice for many nutrition studies without actual food analyses. From such data it has been possible to evaluate quantitatively the diets of population groups and to compare their dietary habits with the standard requirements.

In the two or three years before the war our government became nutrition conscious as a consequence of many of these population studies, as a result of which the Surgeon General came out with the statement that nearly half of the American people were living on diets which were deficient in one or more items. The committee on Foods of the National Research Council was formed, one of its important contributions being to set up a list of recommended dietary allowances which have served as standards during the war both for this country and others. This has been a powerful influence toward better nutrition throughout the world, although the present food shortages are working in the other direction. The recommended allowances may be higher than necessary in some instances, as subsequent work is now showing.

It is true that deficiencies of clinical severity are rare in this country, but there is adequate evidence that pre-clinical inadequacies are relatively common. Incidentally the exigencies of war and its concurrent incidence of severe starvation of peoples in the occupied nations and in prison and concentration camps have for the first time given many of our doctors first hand experiences with the classic diseases of nutrition.

A great deal of important work relative to the vitamins during the past few years has been concerned with the further study and isolation of the lesser items of the vitamin B-complex, as for example, folic acid, pantothenic acid, choline and numerous others. The recent finding that folic acid will cause remission of certain types of anemia and the importance of choline in preventing fatty liver are examples of developments in this direction which have proved to be of use in medicine. Most of these newer B-complex vitamins have not as yet been applied to human nutrition, and undoubtedly research in the near future will add most interesting chapters to the story of this science.

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RECENT DEVELOPMENTS IN THE FIELD OF HEMATOLOGY.

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Progress in both the fundamental and clinical phases of hematology during recent years has been phenomenal. The complexity of bone marrow has been greatly simplified, and the mystery, which for so many decades, surrounded the spleen has become less enigmatic. Both spleen and marrow bear an intimate relationship to each other, and, in turn, to the vital economy of the body as a whole. In the detailed knowledge now available, we have the key to the solution of a whole host of human diseases, some hitherto unrecognized, and, therefore, uncontrolled. Moreover, some of the basic mechanisms are now revealed, whereby new syndromes or combinations of disease syndromes may be detected early, and direct rational measures of control instituted promptly with confidence and with dramatic clinical results.

The most recent significant clinical application of basic information, accumulated from a wide variety of sources through the past ten years of intensive chemical and biological investigations, is that involving so-called folic acid, a derivative of the vitamin B complex. There are five designations which have been somewhat indiscriminately applied to this "group" of compounds: vitamin Bc (essential to growth and hemoglobinogenesis in young chicks), vitamin M (essential to hematopoiesis in monkeys), Lactobacillus casei factor (essential to the growth of these milk-souring bacteria), folic acid (derived from the "foliage" of spinach), and eluate factor (chemical procedure in processing liver, yeast and other natural sources). A conjugate of B_c has been isolated from yeast, having a more complex molecular structure 2.8 times that of the simpler B_c obtained originally from liver. Typical vitamin B_c may be obtained from the "conjugate" on enzyme digestion.

The culminating climax of these fascinating studies came last August (1945) with the announcement by Angier and associates of the chemical synthesis of a compound, recently revealed as pteroylglutamic acid, and ultraviolet and infra-red absorption spectra, crystalline structure and ***biologic activity*** identical with L. casei factor isolated in pure form from liver by Stoksted and Manning (1938). The importance of this discovery cannot well be overemphasized or overstated. The "yield" of this biologically essential molecule from natural sources, such as liver, is exceedingly small, 0.1 ounce from one ton of beef liver, so that to have it available in relatively unlimited quantities the synthetic chemist has immeasureably enhanced its effective application both clinically and in further biologic exploration

Studies in this field were begun in this laboratory in 1940, with Drs. Woolpert, Henry Wilson, Samuel Saslaw and associates in the Department of Medicine and Bacteriology. Rhesus monkeys were used on experimental dietary regimes and it was determined that without "folic acid-containing concentrates" a gradual pan-marrow hypoplasia developed. Langston and associates had previously shown that diets of the Goldberger, black-tongue type were inadequate, and that liver or yeast contained a common essential for normal hematopoiesis in the monkey, "vitamin M." Granulocytopenia occurred in 100 per cent of our dietary deficient monkeys, anemia in approximately 50 per cent. Folic acid concentrate was found to be invariably effective in relieving the granulocytopenia at once, within 24 hours, in our monkeys, and, in those animals showing also anemia, a reticulocyte response was elicited followed by red cell and hemoglobin regeneration entirely comparable to the anti-anemic response to liver extract. Blood thrombocytes also returned to normal.

The translation and transferage of the animal results to clinical patients was begun in the summer of 1943 in Birmingham, Alabama, in association with Dr Tom Spies Patients chronically deficient in many dietary essentials, more particularly the vitamin B complex, were selected, who showed clinically, frequently recurring oral ulcers, associated with a leucopenia hematologically. Folic acid was then given under controlled conditions, and both clinical and hematologic improvement was noted. Later the synthetic molecule was substituted for the natural source with similar results.

With the availability of larger quantities of synthetic folic acid (pteroylglutamic acid) in the early fall of 1945, Spies extended the use of this material to the macrocytic anemias in and around Birmingham with spectacular responses. Darby and Jones reported from Nashville the response of macrocytic anemia in non-tropical spure, and Moore and associates in St. Louis and our own group here, comprising Henry Wilson and Claude Starr Wright, found equally spectacular results in Addisonian pernicious anemia and the macrocytic anemia of pregnancy. Spies then showed that the macrocytic anemia of tropical sprue in Cuba responds promptly. Furthermore, it has been established that those patients sensitive to liver and liver extract may receive folic acid synthetic with impunity and with the maintenance of complete clinical and hematologic remissions. It remains to be proved whether the neurological changes, associated with pernicious anemia in many patients, will remain permanently under control with folic acid.

There is good reason to believe at the present time that pteroylglutamic acid is not the active principle in liver nor is it the extrinsic factor of Castle. The exact and precise role of this extremely interesting and important molecule in the complex chemistry of hematopoiesis remains to be determined, but a new and fascinating chapter is being written in fundamental biological mechanisms and a new and potent therapeutic agent has been made available for the relief of a large number of human sufferers.

THE PRESENT STATUS OF ALLERGY IN CLINICAL MEDICINE

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Allergy in its various forms has been known for ages, but in recent years it has taken on a new importance. A knowledge of its management is even more important now that we know so much more about the condition. Moreover, industrialization and the consequent centralization of 85 per cent of our population seems to have made all allergic manifestations more prevalent. Our attempts to control our climate by means of air conditioning machines are still crude. They merely add to the wide variations in temperature and humidity to which we are already subjected. These variations in our environment produced by modern living put a great strain upon our autonomic nervous systems. As the years go by more and more of us develop imbalances of the nervous system which increase our disposition to develop allergy.

I make mention of this important fact because the students of the new school of psycho-somatic medicine regard the whole field of Allergy with a possessive eye. They point to the fact that a great percentage of psycho-neurotics are also allergic. To support this conception the age-old story is told over and over again of the woman who was allergic to roses and who on one occasion was seized with sneezing when a vase of paper roses was brought into the room. We all recognize that our mental reactions are the function of our brains. Emotional upsets are likely to bring on an allergic attack or to make it more severe than it otherwise would be only to the extent that they disturb the physiology of the individual. Stoic Indians, cows, and dogs are victims of Allergy just as are psycho-neurotics So it would not seem wise to turn the field of Allergy over to Psychosomatic Medicine.

While Allergy has come to be a great joke in the radio world, we in the medical world do not take it so lightly. It has been found to be a cause of asthma, hay fever, sinus disease, hives, ango-neurotic edema, eczema, dermatitis, migraine headaches, colitis, epileptoform seizures, high blood pressure,! and various disorders of the heart and other organs.

The commonest manifestations of Allergy is, of course, hay fever-- properly called timothy allergy in its May and June phase and ragweed Allergy in late August and early September.

In reading the modern literature on Allergy one is thrown into great confusion. The reason for this is that there is a strange misuse of terms. To understand clearly even the popular literature on the subject one must realize that there are several types of Allergy. In the presence of all available knowledge we should recognize the following different types: (1) atopic; (2) non-atopic. Under this last we put: non-reagenic familial Allergy; the Allergy of infection; Allergy to chemicals, including contact Allergy; Allergy to serums; Allergy to physical agents.

The name atopy (literally a "strange malady") was given by Coca to the common Allergy of the ordinary case of hay fever, asthma, hives, and eczema to distinguish it from reactions to serums, ivy and primrose poisoning, and the hypersensitive reactions of tissues to the tubercle bacillus. Coca emphasized that it was a disease limited to human beings, that it was apparently inherited, and finally that it was characterized by the presence in the blood and tissues of its victims of a special kind of antibodies which he called *reagins*. It was later shown that these reagins were transferable to normal individuals. Strangely enough what literally thousands of farm people knew, namely, that dogs, horses and cows can and do suffer from atopic manifestations did not get into medical literature for a good many years.

The idea that atopy is inherited along Mendelian lines may be true. The familial appearance, on the other hand, may mean only that the genes have been

affected in some way by weather, nutrition, or other environmental factors. At any rate the concept of inheritance breeds despair when exhibited in our consultation rooms. Those among us physicians who are of an academic turn of mind cause much needless worry by invoking eugenics. As the late Logan Clendenning rightly observed: "Men are not going to embrace eugenics, they are going to embrace the first likely trim-figured girl with limpid eyes and flashing teeth who comes along in spite of the fact that her germ plasm is probably reeking with hay fever."

It is the third remaining characteristic of atopy named by Coca that constitutes the backbone of the modern treatment of Allergy. This characteristic is the presence of antibodies which may be detected by skin testing and which can be transferred in the serum of the patient to the skin of another individual. This characteristic is generally recognized now and made use of in the search for the cause of the particular allergic manifestation under investigation.

In recent years, Coca has described cases of familial migraine, urticaria, coryza, and asthma in which no reagins could be demonstrated And which apparently did not fall into the regular types of non-atopic Allergy. In those suffering from this disorder Coca has found disturbances of autonomic nervous system in which the offending allergens could be detected by the marked increase in pulse rate which their presence induced. He reported that severance of the sympathetic nerves gives complete and permanent relief.

Although Coca's concept and its interpretation have not been investigated as thoroughly by others as they deserve, they do illustrate that neuroses, organ neurosis, and shock are matters of degree, and that the clinical manifestation represents Nature's attempt to prevent the break-down of a personality.

An Allergy to chemicals accounts for many cases. It consumes a large portion of the workmen's compensation funds earmarked for occupational diseases. Not much has been said in the literature about the possibility of contact other than in plant dermatitis and occupational dermatoses, but certainly most allergists are familiar with cases of coryza and asthma which have been induced through a specific hyper-sensitiveness to oils, fumes and gases. Some years ago I expressed the opinion that these were due to a contact Allergy—an opinion which others more recently confirmed. Many drugs, especially the organic ones, act as allergens. For years aspirin has been the worst offender and the most difficult to manage. But now it is being shoved aside by sulfa-drugs and penicillin. The mechanism has been quite clearly defined by Landsteiner, who has shown that the chemical unites with the serum of the victim to form a conjugate that can then act as a protein allergen. From this point on, the story of each case is exactly like that of serum sickness.

The most common reaction to penicillin is urticaria. This occurs in 5 per cent or more individuals who are undergoing systemic treatment. Vesicular eruptions occasionally occur and they resemble dermatophytids. Penicillin has provoked exfoliative dermatitis.

The allergy of infection is important. Some authorities question its existence. This again is pretty much a matter of terms. The usual definition of Allergy is that it is an abnormal and harmful response to a substance which is not harmful to normal individuals. This is a perfectly good definition of atopen, but it cannot be made to apply to the hypersensitiveness that develops in our bodies toward bacteria with which we have had an encounter. In fact, the severity of our illness during the course of an infection is an expression of this form of Allergy. Upon this fact depends the use of skin testing for the recognition of tuberculosis and undulant fever. There can be no doubt that hypersensitiveness or Allergy, if you will, to bacteria, is a very real thing.

Then there are people who will develop all of the signs and symptoms of one of the allergic manifestations when they are exposed to cold, or heat, or light, as the case may be. These conditions have been named by Duke as physical Allergy.

Compared with them, however, are other members of which heat, light and cold only serve as precipitating factors on account of the nervous imbalance. These and many other accessory factors predisposing at times to an attack of Allergy have at some time been brought forward as the cause of the condition. Among such secondary factors are: barometric changes; temperature changes, especially cold; light; emotional upsets and worries; fatigue; focal infection; acute and chronic infections; constipation, especially with food allergy; deficiency states such as malnutrition, hypochlorhydria; vitamin deficiencies, and particularly thyroid and liver disfunction; and mechanical and chemical irritations, especially dust, dirt, gases, fumes, or fogs.

Skin testing is a convenience when properly performed, and often saves time for the patient. It must be remembered that skin tests do not indicate for certain that the test substance is or is not the cause of his trouble. They are merely clues, the significance of which depends upon the knowledge and skill of the physician and above all upon his familiarity with the properties of his own testing material. For this reason every allergist wants to do his own skin tests in his own way with his own materials. It cannot therefore be emphasized too strongly that skin tests with atopens are only clues to aid and facilitate the search for the real offenders. Good medicine can be practiced without them if necessary.

Like certain other biological phenomena used in medical diagnosis, skin tests require interpretation, because positive reactions may be persisted from previous allergic disturbances, even in other parts of the body. These reactions—for example, pyloric stenosis, infantile eczema, or cyclic vomiting in children—may or may not have been recognized as allergic manifestations at the time of their occurrence. The most common of such reactions is a positive reaction to ragweed or timothy pollen after one season before the initial onset of hay fever in the next season. Finally, at times certain testing materials may be irritating in themselves and so give false positive tests on everyone, or they may become irritating if not properly kept. Extract of house dust, silk, tobacco and certain foods such ns rhubarb and cranberries have to be watched closely in this respect.

All substances that are suspected should be put to clinical trial under controlled conditions, regardless of the results of the skin tests. Likewise, all positive tests must be proved before they are accepted. We see all too many patients who may or may not be allergic to certain substances but who think that they are because they have been told the skin tests to those substances were positive. Too frequently also we hear that the patient was tested and was allergic to nearly everything. It is the rule to be allergic to one or two inhalants and a food or two and possibly a pollen or two but seldom any more.

Treatment.—So far as the relief from the torments of allergy are concerned the greatest advance was made when we were given epinephrin for hypodermic injection. Then came ephedrine with like action but with the advantage that it could be given by mouth. In recent years, the sufferer from severe asthma has been blessed by the introduction of aminophyllin and more recently by its administration in rectal suppositories.

I, with certain others, began the use of histamine some 16 years ago. We found that by frequent injections of carefully graduated doses of very small amounts of histamine we could obtain relief in hives and certain forms of headache with surprising regularity. Then came attempts to tie histamine to some chemical so that it would be gradually released to the body for the purpose of stimulating the body of the allergic to produce enough of the anti-histamine enzyme to destroy at once the histamine released by the struggle between the allergen and its antibodies. In the meantime, the isolation of the enzyme, Histaminase, gave great promise but failed us when put to clinical trial. So the investigators went back to conjugating histamine with various chemicals. The first to be given extensive trial was Hepamine—a conjugate with an azoprotein from horse serum. The

Committee of Treatment of the American Academy of Allergy issued just yesterday its pronouncement that histaminase (Torantil) and Hepamine are of no value in the treatment of allergic diseases. Benadryl holds the stage at present.

Benadryl.—It is supposed that in anaphylactic shock in animals and in the allergic phenomena of human beings there is released a histamine-like substance which accounts for the clinical signs and symptoms. Various anti-histamine substances have been developed, some of them too toxic for general use, but one will hear a good deal of a recently developed benzhydryl compound which has been termed benadryl. When administered orally in doses of 50 to 100 mg. three to five times daily, it is highly efficient in controlling symptoms of acute and chronic urticaria and angioneurotic edema, although the relief is purely palliative. Side effects are not serious: drowsiness, dizziness, dryness of the mouth and dilated pupils may be noted. The drug is given by mouth or by the intravenous or intramuscular route. Preliminary investigations indicate that benadryl relieves pruritus in certain dermatologic conditions besides urticaria; therefore, extensive use of the drug may be anticipated. In my own experience it is a complete disappointment. It only confuses and delays the systematic investigation of hives.

One other drug needs to be mentioned to be condemned and that is ethylene disulphonate. As the Director-General and Editor of *The Letters* of the International Corespondence Club of Allergy, this has caused me no end of trouble. Appearing into respectable circles with a shadowy background, ethylene disulphonate was hailed by the daily press and *Time* magazine as "the one-shot cure" for allergy. It had a great run in Australia at 75 dollars an injection. It lived for awhile in scientific circles in England. In the United States some half a dozen honest men believed that they got good results with it. Careful trial at the University of Maryland and at the University of Minnesota have shown that it has all of the properties of triple distilled water. This left two questions: Are the chemicals which act as reduction enzymes in dilution so great as not to be detectable by ordinary chemical analytical methods, and secondly, what does happen when you give an intramuscular injection of distilled water? Is any histamine-like substance released? These questions appear to me as important, but are being used here as a defense to hold the line while many more vials of the one shot cure can be foisted upon the American physician anxious to give his allergic patient the benefit of the latest thing.

In conclusion, may I warn you against getting lost in the semantics of allergy. Remember that there are seven different kinds. Please be advised that none of the new remedies are much good but that the tedious treatment with pollen and other protein extracts brings about complete and permanent relief in better than 50 per cent of cases and relief in all but a few, that asthma can be controlled and that all forms of hives respond promptly to systematic management and investigation. We in allergy are proud of the clinical results that we get for they are much better than the average in clinical medicine.

We look forward with you to the day when the missing factor whose absence makes a Don Quixote of the tissues of the allergic so that they go off tilting at windmills will be found but in the meantime there is no reason for the allergic to be in any way discouraged.

RECENT ADVANCES IN NEUROLOGY AND PSYCHIATRY

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The last few years have witnessed notable advances in the fields of Neurology and Psychiatry. World War II has served as a vast experimental laboratory in these areas. Modern explosives and present day combat conditions resulted in a large number of brain injuries, some of which were the "open type" of head injury with exposure and laceration of the brain, but a larger number were of the "closed type" of head injury in which the brain is damaged but not exposed. In the field of psychiatry, World War II made it possible to evaluate the psychiatric status of between ten and fifteen millions of Americans who were supposedly in the prime of life. The amazingly large number of these who were found unacceptable for military duty was one of the most alarming pieces of information to come out of the war. Those who were taken into military life were subjected to the rigors of that abnormal existence, and in the process many thousands broke under the strain. It is now well agreed that the major factor in those breakdowns was the conditioning of the personality before induction into military service rather than the actual war experiences, terrible though they may have been.

The large number of neuro-surgical cases that were seen in the War has resulted in many improvements in technique and management. One of these is the use of the substance, fibrin, in neuro-surgery both as a "glue" for severed nerves and in the form of sheets to cover the brain after it has been exposed by injury or after operation. The use of the metal, tantalum, in the repair of nerves and to fill in skull defects is becoming well known. The tissues react much less to tantalum than to other metals which have been used in the past.

The operative procedure of prefrontal lobotomy has been employed in more and more cases in recent years. In this operation an attempt is made to free the cortex of the frontal lobe of the brain from some of its thalamic connections. The functional correlation is a loss of stereotyped emotionally-directed behavior and a turning of the patient's interest away from himself.

The war resulted in a very large number of cases of the interesting condition known as causalgia. This condition was first described at the time of the Civil War but comparatively few cases are seen in civilian practice. Causalgia follows injury to a peripheral nerve, particularly the median nerve, and is marked by burning pain, increased sweating and the signs of vasoconstriction. Studies have shown that this is due to increased sympathetic activity and that it can be relieved by blocking or cutting the sympathetic pathway to the involved area.

The subject of epilepsy is receiving increasing consideration. Much work has been done with the electroencephalograph in studying the brain activity which determines the convulsive and related phenomena. Several new drugs of an anticonvulsant nature have appeared, one of which, Tridione, seems to be particularly effective in treating the petit mal type of the disease. Petit mal Epilepsy is characterized by lapses of consciousness which last 5–30 seconds. During this interval the patient is immobile and out of contact with the world. The attack ends suddenly and he goes on about his business. There may be as many as one hundred of these attacks a day.

The disease, anterior poliomyelitis or infantile paralysis, has been the subject of intensive investigation from many angles. A recent viewpoint which has gained support in recent months is that infantile paralysis is really a systemic disease which is quite widespread and that it is only occasionally and in the late stages that neural manifestations appear. Thus it is believed that the paralyzed

cases constitute but a small percentage of the actual patients with this virus disease. In the treatment of polio, the use of the drug, prostigmin, has been advocated but its value is not as well authenticated as an article in a recent issue of the *Reader's Digest* would lead the public to believe. This only serves to emphasize that lay magazines are apt to be poor sources of technical information.

Alcoholism continues to grow as a neuropsychiatric problem but receives comparatively little medical attention. Recently a treatment for the breaking of the chronic alcoholic habit has been detailed and tested. It is a form of conditioned aversion response in which the reaction is built up in the patient by giving him drugs to cause nausea and vomiting along with his liquor for several days. It should be understood that this treatment is used merely to break a vicious cycle and that its use should be followed by intensive psychotherapy.

Favorable reports continue to appear on the subject of shock therapy for a large variety of psychiatric conditions. Insulin shock is still used in many locations but the trend is definitely toward electro-shock with many variations in technique being introduced. Recently it has been shown that most remissions in the disease occur shortly after discontinuation of the treatment. During a course of treatment by shock therapy it is important for the doctor to be able to distinguish accidental, organic reactions which may occasionally occur. Otherwise the reactions may be mistaken for a part of the original illness reaction and the treatment may be unnecessarily prolonged.

The use of certain drugs to facilitate the investigation of the unconscious field of the mind is becoming more widespread. The procedure is called either narcoanalysis or narcosynthesis. The drug permits the patient to talk about material that would be intolerable to him in the fully conscious state. For these procedures the patient is given a rapidly acting barbiturate drug by intravenous injection The drug is given slowly until the patient is in a mild state of narcosis. Suggestion is then given much as in hypnosis, and then additional drug is given until the narcosis reaches a level in which the patient recalls his memories freely. As the patient comes out of the narcotic state he is given an opportunity to accept his unconscious material and suggestion treatment is used to help him formulate a more adequate synthesis of his reactions.

The recent war did not produce any new psychiatric entities but the conditions under which it was fought gave a new coloring to the basic picture of psychoneurosis. In former wars, particularly in World War I, the common picture was that of hysteria. The First World War was characterized by trench warfare and by dog-fighting aerial combat on a small scale. World War II was fought under much more terrifying conditions—massed aerial attacks against highly concentrated air defenses, precision bombing with tremendous explosives culminating in the atomic bomb, huge battleships, numerous submarines, rocket missles and flame-throwers. In this type of warfare the predominant psychiatric reaction was that of anxiety rather than that of hysteria. Speaking in general terms, anxiety is a deeper psychopathological reaction than is hysteria. There is ample evidence to indicate that modern warfare has become so threatening to life as to be incapacitating to thousands of young Americans. It is not out of place to state, that while it is possible that there may be no limit to engineering genius, there is reason to think of a limit to which the human mind may be traumatized by war. Modern warfare has become so terrorizing as to approach that limit, and men's minds may eventually break down under the abnormally threatening environments which they have created.

It has been said that, "Those who do not learn History's mistakes are condemned to repeat them." There is a distinct possibility that if the world does not heed the mistakes uncovered by World War II we may never be given another opportunity. It is a mistake to attempt the construction of a democratic society of adults when those adults were reared in homes where democracy was not

practiced. Children must learn to emancipate themselves from their parents before they can live without paternalism in government. And they must also learn to curb their selfish drives in order that they may live in a cooperative society. It is also a mistake for a people to fix their allegiance on purely material things, that is to be guided by a purely materialistic philosophy. Material things are individual and personal, while non-material, spiritual values attract group allegiances. A country that relies on purely material values is composed of a multitude of striving individuals and it will lack the common purpose which comes out of a spiritual faith A nation of individuals may well fall before a nation which has a common goal based on a group idealism.

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RECENT ADVANCES IN ENDOCRINOLOGY

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THYROID

In reviewing the matter of endocrine advances during the past year or two, it seems evident that the discovery and subsequent clinical use of Thiourecil is the outstanding achievement Since the original use of the drug by Astwood and his associates in 1943 (1) much interest has centered on the question of what ultimate value Thiouracil would have in the treatment of thyroroxicosis. Considerable skepticism was expressed in the early stages of its use, (2) and conflicting reports of its efficacy have been published during the last few months. Two and a half years have now elapsed since the first use of the drug, and in January of this year a comprehensive report was published by Robert H. Williams (3) giving the effect of prolonged treatment and the toxic reactions observed in 247 patients treated in the Harvard Medical School Clinics. Briefly, it appears to be established that Thiouracil in doses varying from .6 gm. to .3 gm daily will produce remissions in patients with thyrotoxicosis; that thyroidectomy is accompanied by less thyrotoxic reactions when Thiouracil is used, even though the gland is rendered more vascular and friable than with the use of iodides; that combined administration of Thiouracil and iodides is desirable; and that toxic reactions may be expected in 14 per cent of cases. Toxic reactions are found to be more common with prolonged use of the drug and when unnecessarily large doses are used. Most important in the long list of toxic manifestations are leucopenia, agranulocytosis, fever, and various anaphylactic reactions. It has been suggested that the body capacity to bind protein is responsible for the anaphylactic reactions as well for the actual therapeutic effect of the drug (4). Work is rapidly going ahead in the perfection of new anti-thyroid drugs for which hope of non-toxicity is held—and only time will tell to what extent these drugs may supersede surgery in the treatment of thyrotoxicosis.

PANCREAS

Efforts have been centered on improvement of diabetic control by producing insulin preparations which will answer the 24-hour requirement. Protamine-zinc

insulin was thought to be the answer to this, but only in mild cases requiring less than 40 units daily has it been possible to rely on protamine to prevent hyperglycemia during the day, without producing hypoglycemia during the night.

A mixture of regular or crystalline insulin and protamine-zinc insulin in the ratio of 1 : 3 has been quite satisfactory, but is impractical from the standpoint of the ease of administration.

Globin-zinc and histone-zinc preparations have been tried with disappointing results.

In recent months, however, experiments have been made using a bi-phasic insulin containing twenty-five per cent of the protamine in quickly absorbable form, and seventy-five per cent in the present slowly absorbable precipitated form. It is uncertain as yet whether or not this form will prove to be stable for marketable use (7), (8).

MALE HYPOGONADISM

The male climacteric and sterility in the male have received a great deal of attention during these past months. Carl G. Heller has contributed immensely to the understanding of male hypogonadism by his comprehensive classification of the various forms of testicular failure (9). His is one of several excellent reviews of the problem published in the last two years. There is increasing interest in the use of testicular biopsies as an aid in therapeutic evaluation of problems of hypogonadism. Patients having complete hyalinization of seminiferous tubules with partial Leydig-cell failure may be expected to respond favorably to treatment with androgenic substitution therapy, whereas such patients would be totally unresponsive to chorionic or pituitary gonadotropins from the standpoint of subjective clinical relief of symptoms. It is to be understood that spermatogenesis cannot be attained when complete hyalinization has occurred.

In patients demonstrating only an early sclerotic change in the seminiferous tubules, with partial Leydig-cell failure, there is reason to hope that spermatogenesis may be stimulated by the use of chorionic gonadotropins. The duration and expense of both androgenic and gonadotropic therapy are of sufficient importance to justify the wider use of testicular biopsies as an aid in therapeutic prognosis.

Since mumps orchitis is of such significance as a cause of sterility and of early climacteric changes, interesting work is being done regarding its prevention. Gamma globulin from mumps convalescent serum is proving effective in some cases (10).

ADRENAL

Of practical importance from a diagnostic standpoint are the favorable reports concerning the reliability of the Kepler test in Addison's disease (11). Further studies have been made to determine the cause of faulty diuresis and the electrolyte changes which are the basis for the test (12), in the hope that the diagnostic measures may be further improved.

It is highly desirable to be able to discard a test such as the original Wilder test involving salt deprivation which was attended by dangerous reactions.

STEROIDS

The literature in recent months has been laden with reports of the painstaking efforts to isolate and differentiate the various androgenic steroids excreted in the urine (13), (14). It is thought that increasing simplification of methods of extraction and increasing knowledge of the source of the various fractions will prove to be extremely valuable in the diagnosis of adrenal and gonadal pathology. Abnormalities in which dependence for diagnosis is placed on the 17-ketosteroids, include adrenal deficiency in male and females, hirsutism, virilism, amenorrhea, and obesity in females, precocious puberty in males and females, adrenal cortical

tumor, gonadal tumors, and cancer in areas not associated with an endocrine gland.

Pregnandiol excretion in the urine during prolonged amenorrhea is being urged as a rapid, simple test for pregnancy (15). This method of testing was advocated as early as 1931, but has not come into wide use due to difficulties encountered in laboratory techniques. It is not yet certain whether or not the method is sufficiently accurate to justify its use.

PITUITARY

Continued efforts are being made to isolate and purify the various anterior pituitary hormones, but outstanding progress has not yet been achieved.

FEMALE HYPOGONADISM

Menstrual disorders, and sterility are still the outstanding problems in this field. In the last two years, there has been a better understanding of the importance of cyclic therapy in secondary amenorrhea and cases of sustained follicle hyperplasia. The uses of testosterone and progesterone are better understood—and there is a gradual and fortunate trend away from the indiscriminate use of estrogens.

Improved pituitary gonadotropins will eventually fill a great need for physiological ovarin stimulation.

Vaginal smears, stained by specific dyes, are now being widely used as a means of differentiating the various degrees of epithelial cell growth in response to estrogen hormone elaboration. This procedure has provided a practical and simple diagnosis test which may be used in an office.

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DERMATOLOGY AND SYPHILOLOGY

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With the advent of the war in the South Pacific, medication for the prevention and cure of malaria was given to large numbers of men. During the past two years, atabrine (Quinacrine Hydrochloride) has been the drug most commonly used.

Sulzberger reviewed the literature concerning a peculiar lichenoid eruption which occurred in individuals in the armed forces who were receiving atabrine. The eruption began from a few days to several months after the patients began taking the medication. It was common for the eruption to begin with eczematoid changes on the extremities, face and neck, and in some cases it began as a generalized exfoliative erythroderma. Usually after the type of onset, lichen planus-like lesions appeared. These varied from typical, angular, violaceous papules to large hypertrophic lichen planus-like plaques, which later often showed atrophy, pigmentation or depigmentation. Some cases had leukoplakia-like lesions on the buccal mucosa and others had scalp lesions which at times caused permanent alopecia. At the Naval Medical Center in Bethesda, Maryland, atabrine was administered to a group of these patients with quiescent lesions, causing a high percentage of focal flareups of the eruption, and in some cases widespread eczematoid and exfoliating reactions. It is felt that there is little doubt that this peculiar lichenoid dermatitis is a drug eruption due to atabrine.

There are increasing reports of dermatitis due to the use of penicillin. Binkley and Brockmale reported a case of epidermal and dermal sensitivity to sodium penicillin, as proven by patch, scratch and intradermal tests. They reported another case who developed a dermatitis about six weeks after first exposure to penicillin but in whom the patch and scratch tests were negative. However, in this patient when penicillin was injected intramuscularly, there was edema and a confluent papular eruption involving the hands and feet. The skin of the feet had never been previously exposed to penicillin but had been the site of a chronic dermatophytosis. Other cases of a dermatitis developing at the site of previous fungous infections have been reported, and Sulzberger suspects that this localization may be due to a common allergenic fraction in the fungi found on the skin and in penicillium notatum. Cormia reported a serum sickness-like syndrome with generalized urticaria, mild arthralgia, and lymphadenopathy. This is now known to be a common reaction to penicillin. Miliaria-like and erythrema nodosum-like eruptions have also been reported.

About five years ago, there began on the East Coast of the United States an epidemic of ring worm of the scalp involving boys and girls of prepuberty. This has gradually spread to the Midwest and within the past eighteen months has assumed epidemic proportions in the State of Ohio. There are two organisms which commonly cause ring worm of the scalp: *Microsporon audounini* and *Microsporon lanosum*. These two organisms differ in that infections due to *Microsporon lanosum* commonly cause a severe inflammatory reaction and can be cured with ease by local medication; whereas those due to *Microsporon audounini* show almost no inflammatory response and are most resistant to any local therapy. In this epidemic, the first of its kind in the United States, the offending agent has been *Microsporon audonini*. The Wood's light, which is ultraviolet light filtered through cobalt glass, causes infected hairs to shine with a bright green flourescence, and is an indispensable diagnostic tool. At the present time, the treatment which is accepted and efficacious in these cases, is temporary epilation by means of x-ray.

Urbach recently described a syndrome usually presenting a clinical picture of furnuculosis, sweat gland abscesses, eczema and pruritis, in which there was a

normal blood sugar curve but microchemical examination of the skin itself showed the sugar content to be higher than normal. A low carbohydrate diet sometimes combined with insulin, caused marked improvement in the dermatoses.

Kaposi in 1897 described a varicella-like eruption which occurred in infants as a complication of eczema. Some authors have stated that this entity is the same as eczema vaccinatum. In December, 1944, Lane and Herold described five patients with this type of eruption, only one of whom could possibly have been infected with the vaccinia virus. In February, 1945, Lynch described a group of four cases with a herpetic eruption complicating atopic eczema. In three cases, he showed presumptive evidence that the herpes simplex virus was the causative agent and in one case, laboratory studies permitted the conclusion that the virus of herpes simplex caused the eruption. He suggested the name "eczema herpeticum." Blattner, et al., reported a case of a boy, age fifteen months, who had had atopic eczema since the age of six weeks, had never been vaccinated against smallpox, and who developed fever and an acute exanthema of the herpetic type. By animal experimentation, histo-pathologic and immunologic studies, they established the causative agent to be the herpes simplex virus. There seems to be little doubt that the herpes virus has been proven to be the causative agent of a varicella-like eruption, complicating atopic dermatitis.

Stryker and Halbeisen described a group of cases with cutaneous lesions consisting of a patchy or diffuse, scaly erythroderm involving the sides of the neck and anterior shoulders. These patients also exhibited a few signs of a mild vitamin deficiency, although all declared their diets to be adequate. Blood studies revealed a macrocytic anemia. Crude liver injections caused a disappearance of the eruption and a return to normal of the blood picture These studies may throw light on some of the bizarre eruptions appearing around the shoulder girdle which commonly have been called neuro dermatitis.

In dermatologic therapy, a few new, useful agents have been introduced. Penicillin has been most promising in the treatment of the pyodermas. As in other fields of medicine, it has been tried indiscriminately in the treatment of dermatologic entities in which therapy has been unsatisfactory. It is not efficacious in pemphigus vulgaris, dermatitis herpetiformis, eczema, seborrheic dermatitis, acne vulgaris and the chronic dermatoses involving the hands.

Two new fatty acids, namely, propionic acid and undecylenic acid, have been introduced and widely used as a treatment for superficial fungus infections.

Eddy and his workers at the U. S. Bureau of Entomology, have developed formulas containing benzyl benzoate, pyrethrins, undecylenic acid, 2-4 dinitro anisole and DDT, in the treatment and control of head lice, crab lice and scabies. They have been largely responsible for the excellent control of these conditions in the armed forces.

The combination of Vitamin B complex and hydrochloric acid has been reported by at least three workers, to be helpful in the treatment of vitiligo.

Two new preparations, pyribenzamine (Ciba) and benadryl (Parke, Davis), appear to be useful drugs in the control of reactions caused by histamine. They are especially promising in the treatment of urticaria and although they are nonspecific as far as the allergens producing the urticaria are concerned, they appear to be specific as far as the mechanism by which some of these allergens produce the disease.

Peters, after studying the chemical content of the exfoliated skin from patients with exfoliative dermatitis, treated them with cystine with good results. He suggested that in an attempt to restore the epithelium, the body had depleted its sulfur containing amino acids.

Cannon reported successful results in five cases of acute disseminated lupus erythematosus by the oral administration of iodine. He tried the treatment when he noted improvement in a case of acute disseminated lupus erythematosus

who had been given a dye containing iodine preceding roentgenograms of the gall bladder.

The most important advance in the field of syphilology is treatment with penicillin which appears to be most valuable in the treatment of early syphilis. The trend in treatment is to use a combination of penicillin and the heavy metals. Eagle, et al., have shown penicillin and Mapharsen to be synergistic in the treatment of experimental syphilis. Platou, et al., treated sixty-nine infants with early congenital syphilis and reported the immediate response to be encouraging. Rose, et al., gave a preliminary report on seventy cases of central nervous system syphilis treated with penicillin. The greatest improvement was in patients with general paresis. Dolkart and Schwemlein found it necessary to discontinue penicillin in the treatment of two cases of cardio-vascular syphilis because of the development of severe anginal pain. In general, it may be said that penicillin is a useful agent in the treatment of syphilis, but that no long term evaluation can be made as yet.

The incubation period of syphilis is considerably longer than that of gonorrhea and the effective dose of penicillin for syphilis is much larger than for gonorrhea. The small doses of penicillin which are successful in the treatment of gonorrhea may in a concomitant case of syphilis temporarily suppress the primary, secondary and serologic manifestations of early syphilis. This makes it mandatory that all cases of gonorrhea treated with penicillin be followed serologically for six months to one year, rather than three months as has been previously recommended.

Some important work has been done on the serologic verification tests. Rein and Elsberg examined six verification tests to determine their value. They found none of these methods to be of value in distinguishing consistently between true positive (syphilitic) and false positive or non-syphilitic reactions. It was their feeling that present verification tests are of no value in the sero diagnosis of syphilis. Scott, et al., in another study came to the same conclusion.

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RECENT ADVANCES IN ANATOMY

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In this brief survey only those topics which appear to be of special interest to members of this section have been selected for discussion.

The number of human embryos of the first two weeks of development recovered by American embryologists has been almost doubled during the last six years. This is a remarkable achievement when it is realized that it was accomplished largely by the joint efforts of two men—Hertig and Rock, of the Staff of the Free Hospital for Women at Brookline, Massachusetts. Prior to their discoveries our knowledge of early human development was based on hardly more than a dozen embryos scattered widely among the laboratories of Europe and America.

Obviously the phenomenal success of these searchers for human specimens seldom or never seen, was not a matter of mere chance. They undertook a systematic and organized search for human ova in uteri of patients of high fertility who were willing to cooperate by keeping, while awaiting hysterectomy, a careful record of menstruation and coitus dates. These records enabled them to determine the likelihood of the presence of a conceptus and to judge more accurately the age if one were found.

In 1942, they announced the recovery of two normal human ova of 7½ and 9½ days of age respectively, which represented at the time the youngest human embryos ever observed. The younger embryo was in the process of implantation, the older one had just completed this process. Last month at the annual meeting of the Association of Anatomists at Cleveland, they reported the finding of a young human blastula free in the cavity of a uterus in the twenty-first day of the cycle. The probable fertile coitus occurred 4½ days previously. This conceptus is judged to be 4 days old. It consists of nine blastomeres of varying size and shape. Since some of the blastomeres are multinucleated, it is concluded that the specimen is abnormal, hence the 7½ day old embryo still remains as the youngest known normal human embryo.

A study of twelve very young embryos of their collection has been reported in some detail. Of this number seven were normal and five abnormal, the latter being so pathological as to indicate early abortion. It is interesting to note that all the normal embryos were implanted on the posterior wall, and all the abnormal on the anterior wall.

They conclude, 1) that nidation takes place between the fifth and eighth day following fertilization, 2) that the post-ovulatory phase of the menstrual cycle is less variable in duration than the pre-ovulatory phase, 3) that ovulation regularly occurs 14 days prior to the onset of menstruation, thus a women with a menstrual history varying from 25 to 30 days has an ovulatory period ranging from the 11th to 16th day of the cycle

The recent literature clearly shows a trend in anatomical investigations away from strictly morphological studies toward histo-physiological and histo-chemical problems. The aims of histophysiology are to interpret structure in terms of function and to provide a structural basis for understanding functional processes. In histochemistry the objective is the localization and identification of chemical substances in respect to the structural organization of the tissue elements.

Obviously histophysiological studies require the use of both histological and physiological methods. The usual procedure is to study the morphological changes associated with varying states of functional activity. Modern endocrinology owes much to this type of investigation. Of the very recent histophysiological contributions one only has been selected for discussion.

Dougherty and White, 1946, demonstrated that the adrenal cortex exerts a controlling influence over the number of lymphocytes in lymphatic tissue and in the circulating blood. Adrenalectomy in animals produces lymphoid hyperplasia and lymphocytosis whereas the injections of adrenotropic hormone or adrenal extracts produce lymphopenia in lymphatic tissue, lymphocyte degeneration and an increase in plasma cells. It has been shown also that augmentation of the normal quantity of circulating adrenal cortical secretion produces a significant increase in serum globulin and in circulating antibodies, which suggests that disintegrating lymphocytes are sources of these substances.

Histologists have long been interested in the localization and identification of chemical substances in cells and tissues. They have been over-zealous many times in interpreting their staining reactions on a chemical basis. Of the many methods that have been proposed in the past but a very few, such as the Sudan staining for lipids, the Prussian blue reaction for iron, and the nucleal reaction for chromatin have been accepted with certain limitations as trustworthy.

In the last two decades, particularly the last, investigators with experience in both histology and chemistry have reported many new histochemical methods. The procedures are diverse but all depend on the physical and chemical properties of the tissue constituents.

Differences in solubility and in rate of sedimentation on centrifugation have been employed to separate and isolate various cellular components for chemical analysis. The amazing feat of separating intact mitochondria from liver cells was accomplished by Bensley and Hoerr in 1934, submicroscopic particulates by Claude in 1938, glycogen particles by Lazarow in 1942, intact nuclei by Dounce in 1943 and nuclear chromatin in pure state by Claude and Potter and by Mirskey and Pollister in 1943. Methods and results are discussed in Volume X of Biological Symposia.

Analytical chemical analyses of the isolated mitochondria and submicroscopic particulates show that both are complexes of proteins, nucleo-proteins and lipids, the mitochondria containing more protein and less lipid than the particulates of Claude.

Identification of substances in situ in microscopic sections, either fresh or fixed, has been accomplished by various means; behavior in polarized light, fluorescence,

microincineration, ultra violet absorption and by highly specific and sensitive chemical reactions, the last mentioned has the advantage of superimposing a chemical picture on a morphological picture. An evaluation of these methods was published by Lison in 1936.

More recently introduced techniques that are now being extensively studied and applied are discussed in a recent review of histochemistry by Dempsey and Wislocki, 1946. It has been found that treatment of sections with the enzyme ribonuclease destroys the characteristic basophilic staining reactions of the Nissl granules in nerve cells, of the cytoplasmic granules of the basophiles of the anterior pituitary, of the cytoplasm of serous secreting glands, and of the trophoblast of the placenta. Thus, it appears that all those substances in cells which lose their characteristic basophilic staining reaction after digestion with ribonuclease represent or at least contain the ribose type of nucleo-protein.

It has also been demonstrated that the adrenal cortex, ovarian follicle, corpus luteum and trophoblast cells of the fetal placenta contain a lipid soluble substance that will convert phenylhydrazene when applied to sections to yellow phenylhydrazones. This is a well known test to aldehydes and ketones, but since this substance is lipid soluble and since it is present in the organs which are known to produce the keto-steroid hormones, it is concluded that this test demonstrates the presence of such substances in tissue sections.

The localization of the alkaline and acid phosphatases can now be visualized in microscopic sections. Since the phosphatases are believed to participate in the metabolism of phospho-lipids and sugars and in the absorption of sugars and fats through cellular membranes, the visualization of the precise location of these enzymes affords a valuable histological method for the study of cellular functions A number of papers dealing with this subject has just been published. It seems that the enzymes are accumulated between the blood stream and the site of deposition of glycogen. They are present in the distal part of the absorbing cells of the small intestine. The prostate gland contains only acid phosphatases. Acid phosphatases accumulate in the syncytium of placentas near term, whereas alkaline phosphatases are present throughout gestation.

The interest of histologists in histophysiological and histochemical studies has prompted Dempsey and Wislocki to propose the term physiological histochemistry for this new discipline which correlates morphology, chemistry and physiology.

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SOME ADVANCES IN THE CONTROL OF TOOTH DECAY

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Among civilized peoples today decay of the teeth is one of the most prevalent of disease conditions, affecting 85–90 per cent of all such individuals. It is distinctly a disease of civilization as attested by the fact that primitive populations show an incidence as low as 3–10 per cent. Its progressive increase has paralleled that of the increased use of refined food, especially the carbohydrates. Despite the fact that reference to tooth decay has occurred among the writings of all people and in all times, some of the earliest scientific experiments and observations were made by Dr. W. D. Miller (1) about 1880. He isolated 22 bacterial forms from the mouth and decayed teeth and demonstrated that 16 had the ability to form acids when mixed with carbohydrates. He subjected extracted teeth to such mixtures and produced lesions comparable to those occurring in the mouth under natural conditions. The fundamental observations of Miller which related the oral acid forming bacteria and carbohydrate food material to tooth decay have never been successfully contradicted and are today a working basis for any method of control. After Miller's death (1907) little of real value was added to the knowledge of tooth decay until 1923. Starting then and working continuously for several years a group consisting of dentists, bacteriologists, nutritionists and physiological chemists began an intensive study of the saliva and blood of decay susceptible and decay resistant children, using orphanage populations. As a result they were unable to demonstrate any consistent significant group differences in the chemical nature of the blood or saliva (2, 3). However, in a bacteriologic survey (4, 5, 6, 7, 8) of decay free and decay susceptible individuals they found *L. acidophilus* consistently present in large numbers where tooth decay was active. This bacterium was absent, or only sporadically present in small numbers, where tooth decay was inactive. This relation has been substantiated by others (9, 10) and the relatively few contrary findings (11) are minimized by the fact that similar bacteriologic methods were not employed.

It has been adequately demonstrated that there is a direct relationship between the occurrence of *L. acidophilus* in the saliva and the activity of tooth decay, and that the quantitative estimation of salivary *L. acidophilus* is a relatively accurate index of the degree of such activity. That there are other acid forming bacteria involved is understood. The *L. acidophilus* count is used only as an index of the total acidogenic process.

There is definite evidence (12, 13, 14) of the effect of the ingestion of sugar on the activity of oral acidogens. Their activity and the resultant tooth decay are directly related to the amount of refined sugars in the diet of susceptible individuals. About 85 per cent of us are susceptible, about 5 per cent never have tooth decay, regardless of sugar intake, while about 10 per cent are so susceptible that refined starch continues to be a factor in their tooth decay when all refined sugars are withdrawn from the diet.

This is the now generally accepted status of the factors involved in tooth decay. The picture is incomplete, mostly in the area of true immunity which seems to have no relation to dietary factors. In these cases there is no acidogenic oral flora and attempts to grow *L. acidophilus* in either the saliva or the blood of such individuals have failed (15). There is some evidence (21) that this may be due to an ability to convert certain amino acids into ammonia nitrogen which acts as a deterrent to the growth of acid forming bacteria in the mouth.

Since 1939, the beneficial results of small amounts of fluorides naturally present in water supplies has been proved. Teeth of children which have developed

during the period of consumption of such water have shown a markedly lowered caries rate (16). Such teeth contain a greater amount of fluorides (17) and calcium salts are known to become less acid soluble through the addition of fluorine.

Within the past few years it has been reliably reported that the use of carcanimide (18) in dentifrices and mouth washes, synthetic vitamin K (19) in chewing gum, ammonia mouth washes, reported topical applications of sodium fluoride solutions on the cleaned surfaces of the *teeth of children* (24, 25, 27, 28) and the temporary elimination of refined carbohydrates from the diet (29) have each reduced the rate of tooth decay.

All these methods are based on possibilities of control which are compatible with what is now known about tooth decay, to wit, that it is initially a localized decalcification of hard tooth tissue by acid formed by oral bacteria acting on carbohydrate food material. These possibilities are:

1. Decreasing the intake of foods from which oral bacteria can form acids. This is the dietetic control and is being used for individual cases.

2. Direct inhibition of the growth of oral acid producing bacteria This can be accomplished by the use of synthetic detergents (wetting agents), urea and ammonia.

3. Interference with the chain of reactions necessary to produce acids, such as occurs in the presence of synthetic vitamin K (quinone).

4. Reducing the solubility of the calcified tooth tissues in acids such as occurs in teeth developed on natural fluoride waters and such as may be the result of fluoride solutions topically applied to the enamel of children's teeth.

Of the above, the direct inhibition of bacterial growth and the interference with acid formation can be accomplished only for a very short time and to produce results they must be carried out immediately after any carbohydrate, especially refined sugar, has been eaten. Attempts to control tooth decay by such means are still very much in the experimental stage and more data will be necessary before their usefulness can be accurately evaluated.

Diet control will produce results and is being used rather widely. Its chief limitations are that it is an individual treatment and that patient cooperation is absolutely necessary. A period of six weeks divided into three two-week periods is used. The first period eliminates all free sugar and reduces other carbohydrates to 80–100 grams per day. If strictly followed it will reduce a high *L. acidophilus* count to zero in most cases. The second period introduces an increased amount of carbohydrate (not refined sugar) and the third period allows as much sugar or sugar sweetened food as desired at one meal per day. Salivary *L. acidophilus* counts at the end of each period show little or no increase, provided the prescribed diet has been followed. Following the dietary treatment, patients are checked at six-month intervals for two years. It is not unusual to find the *L. acidophilus* count still quite low at the end of this period. The length of the beneficial effect is proportional to the patient's ability to limit his sugar intake to reasonable amounts, following the restricted diet period.

Repeated topical applications of sodium fluoride solution to the cleaned surface of children's teeth is a practical procedure and will reduce the future occurrence of tooth decay by about one-third. This also has the limitation of being an individual method of treatment and is thus restricted in its application. It is practical and requires only that the patient report for treatment.

The fluorination of communal water supplies now deficient in natural fluorides (less than 1.0 P.P.M.) offers the best possibilities of wholesale reduction of tooth decay. In order to determine whether or not artificially fluorinated water can accomplish the same results as have been proven for naturally fluorinated waters, large scale controlled experiments are now under way (22, 23). The results will not be known for 8–10 years since they can only be judged on the basis of the decay which will occur in the teeth now being developed by children on such a water

supply. If successful, this will offer a public health measure of tooth decay control which can be applied to all children raised on communal water supplies. This would reach about two-thirds of our child population. If it is as effective as natural fluorides it will effect a reduction of tooth decay in children to about one-half of its present rate.

In summary, we are now in possession of considerable information, the application of which could markedly reduce tooth decay if it could be easily and generally employed. There is no proof that tooth decay is related to dietary deficiencies but there is a great deal of proof that it is related to the excessive consumption of refined carbohydrates, especially sugar.

Sugar rationing and threats of sugar shortages are amusing. From the standpoint of tooth decay the complete elimination of all refined sugar from the diet would be a godsend to the present generation of children. Neither would it do harm to the waistline and few remaining teeth of their elders who still persist in the erroneous belief that candy is essential to child development and happiness.

While the proper use of fluorides will reduce tooth decay their role is palliative. Specifically fluorine acts to slow down the destructive effect of localized acid production. This acid would never have been generated in the absence of acid forming oral bacteria nourished by refined carbohydrates from food.

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SOME APPLICATIONS OF ATOMIC ENERGY TO DIAGNOSIS AND THERAPY

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Applications of atomic energy, used here synonymously with nuclear energy, for therapy began when radium was first used for treatment, since the rays emitted by radium and its disintegration products are manifestations of nuclear atomic energy. In 1932 Professor Ernest Lawrence invented the cyclotron and since then radioactive species of almost all of the elements have been generated in it. Many of the artificial radioactive species of those elements which make up our bodies disintegrate too rapidly to be useful to us in medicine. But some of them produced by bombardment in a cyclotron, and recently by fission of certain heavy atomic nuclei, last sufficiently long that they can be utilized by physicians. A few of the applications to diagnosis and therapy thus far explored are briefly summarized in the following discussion.

The extreme sensitiveness of appropriate detecting devices for the emitted rays makes it possible to measure accurately the concentrations of the elements in dilutions often as great as a billion or more times beyond former methods, and studies are thus possible with elements normally present in the body in minute amounts without disturbing existing physiological equilibria.

Radio-Iron.—During the war radioactive red blood cells were obtained (1) in which the hemoglobin molecules had become "tagged" with radioactive iron injected into volunteer donors. Determinations by physical methods of the time that the radioactive cells remained in the circulating blood of volunteer recipients after treating the donor blood with various adjuncts made it easy to determine the best preservative for addition to the whole blood collected on the coasts of the United States and flown to the battle fronts.

Last year a British worker (2) used such "tagged" erythrocytes to circumvent the difficulties formerly encountered in determining blood volume, and found the value to be 73.5 cc. per kilogram of body weight in normal subjects. Compensated heart cases had blood volumes in close agreement with normal, but in a case of heart failure, there was a considerable increase in both the amount of blood corpuscles and the circulating blood volume. In another case of heart failure treatment resulting in compensation was associated with a 28 per cent decrease in blood volume and an 18 per cent decrease in red blood cells.

Other investigators (3) have shown that anemic dogs absorb "tagged" iron rapidly from the gastro-intestinal tract whereas absorption is slow when the iron level is adequate. Only 0.3 per cent was absorbed in 23 hours after the last feeding in non-anemic dogs, but 59 per cent of the radioactive iron was absorbed by anemic dogs in the same time. Four per cent of the absorbed labelled iron was contained in the erythrocytes in the first case as compared with 78 per cent in the anemic dogs.

Radio-Iodine.—The thyroid gland normally contains about one part of iodine in a thousand whereas the blood averages less than one part in ten million. Because of this marked localization and because radio-iodine emits gamma-rays, it is easy to carry on many diagnostic and metabolic studies *in situ* merely by placing a sensitive detecting device over the gland. Hamilton and co-workers (4) found that, when 0.1 microgram of sodium iodide, the iodine of which was labelled with radio-iodine, was administered to patients with thyroid disease, the following percentages of the dose had localized in the thyroid at the end of one day:

Diseases	*Per Cent Uptake*
Hypothyroidism without goiter	2.0
Normal controls	18.5
Non-toxic goiter	25.0
Toxic goiter	61.5

Certain cancers of the thyroid show accumulation of radioactive iodine not only in these structures but also in metastases to the bones (5). In such cases it is a hope, when sufficient radio-iodine becomes available as a by-product of fission of uranium-235 or of plutonium, that cures may result from the radiation emitted by large doses. Similarly, large doses of radioactive iodine have been reported to be effective in treating toxic goiters by such internal radiation. The dangers of radiation of surrounding vital structures incidental with roentgen-therapy are largely avoided by this method.

Radio-Sodium.—Radioactive sodium produced in a cyclotron has recently been used as an aid in the diagnosis of peripheral vascular diseases (6). It was injected in such a small amount as to be of no harm, as isotonic sodium chloride, into an antecubital vein and a foot was then placed close to a tube sensitive to the gamma-rays emitted. Dependent upon the arm-to-foot circulation time, the tube was activated in twenty to fifty-five seconds in normal subjects as the radioactive sodium was carried into the foot. The radioactivity of the foot continued to increase until the concentration became more or less uniform throughout most of the body. A plot of increased radioactivity of the foot against time after injection reached a plateau in about forty minutes normally as equilibrium was reached. When the circulation to the foot was impaired, the plateau was not so high nor reached so quickly as normally.

In a patient with peripheral vascular spasm the plateau was only about one-third as high as normally. After bilateral thoracolumbar sympathectomy was performed, the plateau was far above normal. Other conditions in which the plots were of diagnostic value were arteriosclerosis; thrombo-angiitis obliterans; various vascular obstructive lesions; scleroderma; and Raynaud's disease. In some cases the new technique may furnish information concerning vascular supply which is valuable in determining the level at which amputation is necessary.

Radio-Phosphorus.—Because phosphorus is present in all cells and it can readily be made radioactive in a cyclotron, it has been employed far more commonly than any other artificial radio-element in biological tracer studies as well as in therapy. Usually it is converted to disodium hydrogen phosphate for administration.

Numerous investigators have sought to treat tumors with radio-phosphorus by differential localization in them, since cells in rapid mitosis utilize much phosphorus for the formation of nucleoproteins and it might therefore be expected that these cells would localize more or less selectivity much of an intravenous dose of radioactive sodium phosphate and thereby be destroyed. The fundamental principle involved here is that the destructive ionizing radiation emitted by the radioactive phosphorus will penetrate only for limited distances so that it will affect adversely only the tissues in which it is localized. Radio-phosphorus has been explored extensively in leukemias, lymphosarcoma, multiple myeloma, etc., but early hopes for effectiveness in soft tissue tumors have not been wholly realized. This is so largely because the phosphate salts in bone are relatively so insoluble that too much destruction of bone marrow results from the high localization in bone when sufficient amounts to affect such tumors adversely are administered. The extensive studies of Dean Doan and Professor Wiseman of the College of Medicine with radioactive phosphorus generated in the cyclotron of the Physics Department of The Ohio State University during the last six years have shown, as well as the work of others, that radio-phosphorus is highly efficacious in the treatment of polycythemia rubra vera and promises to supplant all former therapeutic measures in this disease. They have used it successfully in the treatment of chronic leukemias, especially myelogenous leukemia.

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RECENT ADVANCES IN BACTERIOLOGY

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As is true of many sciences in this period of scientific advancement, Bacteriology has extended its frontiers in many directions. In so doing Bacteriology has joined hands with numerous scientific neighbors with the result that subject boundaries have become indistinct, and many areas are held jointly by two or more sciences. Furthermore, the advanced nature of modern research requires a mutual exchange of techniques among sciences and demands their close association in research for the solution of the problems that now present themselves for study. The circumstances of the highly technical war that we have just waged have shown us how necessary and effective is this teamwork among sciences

Things being as they are, then, advances in Bacteriology are not circumscribed by limitations implied by the term "Bacteriology," but are associated with progress in allied fields. During the war, many advances were particularly concerned with the applications of scientific knowledge on a large scale.

With this understanding, let us briefly consider the advances recently made in four fields arbitrarily designated as (1) General Bacteriology, (2) Medical Bacteriology and its Applications, (3) Viruses, and (4) Medical Mycology.

(1) *General Bacteriology.*—For some years the sulfa drugs have been studied and employed as chemotherapeutic agents, with results known to all. Bacteriology has developed the techniques of experimental evaluation and of the control and interpretation of clinical trial. The mode of action of sulfa drugs was early recognized as a problem of bacterial metabolism, and while the explanation is still theoretical and not always applicable, it is now most generally thought to be of this sort: bacteria that are sensitive to sulfa drugs owe this sensitivity to the facts, first, that they, like most other living things, require vitamines or vitamine-like substances for their growth and development; second, that they are unable to distinguish between these essential substances and structurally similar compounds such as the sulfa drugs; and third, once having taken up the metabolically inert sulfa molecule the bacterial cell is incapable of utilizing the growth factors. Bacteria thus held in a condition of stasis readily succumb to the defense mechanisms of the host.

Antibiotics, those substances produced by molds and bacteria and antagonistic to other microorganisms, are likewise well known as therapeutic agents. Bacteriology has established methods of laboratory assay and by such means can tell the concentration of an antibiotic in the body fluids of patients. The mode of

action of this biological product is as yet undefined, but it does appear that the antibiotics now in use exert their effects by bacteriostasis when the concentration of the drug is low and by bacteriocidal and bacteriolytic actions when the drug is is high concentration.

For some time it has been known that the types of pneumococcus are differentiated according to the specific carbohydrate composition of the capsule, and that a pneumococcus could be changed from one type to another by certain laboratory procedures. The interesting observation has recently been made that exposure to desoxyribonucleic acid from an encapsulated Type III transforms an avirulent non-encapsulated Type II into a fully virulent Type III pneumococcus. In this way, one variety of bacterium is converted to another by the presence of a substance of known chemical composition, not unlike the determining action of a gene in higher forms.

These instances of alteration of bacterial metabolism by the presence of certain substances point to the so-called "phenomenon of interference" in bacterial physiology. With this phenomenon brought to the attention of investigators, other examples are constantly being described having to do with the competition of bacteria and viruses for food elements, some of which are chemically defined. This type of work involves a detailed chemical and biological approach to the study of enzymes, bacterial metabolism and parasitism and will yield fruitful results with further exploration and analysis.

Advances in biophysics, as applied to Bacteriology, are only begun, but already there is much promise in the use of tagged and radioactive elements in the study of bacterial metabolism. It is expected that the utilization of tagged elements will disclose how molecular chemical reactions are brought about by bacteria and how the chemical structure of bacteria is built.

The electron microscope has been used to explore, by its high magnification, the finer details of bacterial composition and the shape and size of viruses. Attention has been concentrated on the finding of minute structures in bacteria and the possibility of their representing nuclear elements. Thus far, no definite nucleus or chromosomal mechanism has been established, but the interpretation of the physical findings combined with histo-chemical studies may shed light on this basic and baffling question in bacterial morphology and genetics.

(2) *Medical Bacteriology and Applications.*—It is unnecessary to dwell on the valuable improvement of diagnostic methods by the laboratory workers of the Armed Forces Not only has the best effort of highly qualified experts been spent on this practical question, but also the circumstances of military activities in so widely scattered parts of the world have necessitated a development of techniques in microbiological fields hitherto not possible.

The control of air-borne infections has been studied intensively by military and civilian groups. The scientific approach has consisted of the development and application of methods for the determination and control of the factors involved in transmission of respiratory bacteria, such as particle size, conditions favoring suspension and transmission of dust and respiratory droplets laden with bacteria, devices to sample air and to count its contained bacteria, methods of dispensing disinfecting aerosols in barracks, schools and other common rooms, the efficiency of germicidal light, and the oiling of floors and bedding to keep down contaminated dust. Above all, much effort has been spent on the interpretation of the results of using one or another of the many devices devised. This whole program has had and will continue to have far reaching results in the difficult field of respiratory infections.

Medical Bacteriology has been much concerned with drug fastness to sulfa drugs and antibiotics. Too often for completely satisfactory results, bacteria either in a single patient or passed from person to person have proved by bacteriological methods to be resistant to the drugs in use. This seems to be more a

matter of selection and survival of drug-fast bacteria in a bacterial population than the sudden conversion of a whole population to the state of resistance. Once the fastness fortuitously occurs, it persists in the strain transmitted to subsequent hosts. Medical bacteriological laboratories now use techniques for the determination of such fastness and report the findings to the clinician or public health official who takes the observation into account in further management of the situation.

The applications of Medical Bacteriology would not be completely recounted without a reference to the improvement and probably increased effectiveness of certain bacterial vaccines, such as those against typhoid and paratyphoid fevers, cholera, plague and tetanus. Also, reference should be made to the measures taken to combat hazards of water-borne infections and bacterial food poisoning experienced by our men under conditions of combat and service in the near and remote parts of the world from the Equator to the Arctic Circle. Here, methods of sanitary control, preparation of safe food, vaccines and education reduced greatly the likelihood of food and water-borne disease. Similarly, the development and application of insecticides were instrumental in reducing the incidence of insect-borne disease.

(3) *Viruses.*—The study of viruses and virus diseases, well advanced before the war, was given a marked impetus by the necessities of military activity. The solution of earlier problems was advanced, such as in influenza in which laboratory diagnostic methods were improved, epidemiology studied, and vaccines developed and applied. Similarly, typhus received much attention with the result that serological tests were devised, the relation of epidemic typhus of man and endemic typhus of rats was more clearly defined, and the typhus vaccine was improved. Attention to scrub typhus, met by our men in the Far East and Western Pacific, necessitated intensive studies that disclosed the native rodents as sources of infection, insects as vectors, and the elimination of these factors in camp sites as measures of control. Progress has also been made in the development of vaccine.

Atypical pneumonia and infectious hepatitis occurred seriously during the war, the former in increased incidence and the latter in epidemic form. The specific cause of atypical pneumonia is as yet undetermined, although bacteria are thus far excluded. It is interesting that so many cases should be recognized clinically in recent years, as if it were a new disease, and yet no one virus of several proposed has convincingly been shown to be the sole specific cause. Infectious hepatitis, first seen arising from a contamination in the human serum component of yellow fever vaccine, proved serious also in large spontaneous epidemics. Lacking a susceptible experimental animal, human volunteers have been used in studies on etiology, and it now looks as though the disease is due to a virus present in patients' feces and entering by the mouth. The etiologic agent may be related to those of catarrhal jaundice and of hepatitis occasionally following injections of human serum.

Recent advances in the study of poliomyelitis have not settled the question of the modes of transmission and entry of virus into the human body. Detailed epidemiological studies, histological examinations of nervous tissues, and the finding of virus in the upper respiratory tract coincident with the infectious period of persons for others point to a substantiation of the theory of contact and droplet methods of transmission, as opposed to the theory of intestinal source and entry of virus.

The classification of viruses has been a troublesome question for those who desire to arrange their subject matter in orderly fashion. It seems now as though, by our continued detailed study of the various features of viruses and virus diseases, that at least four groups can be identified: viruses of some forms of encephalitis (St. Louis, Japanese B, Russian Spring-Summer, and louping ill); viruses of relatively large size and of similar antigenicity (psittacosis, lymphogranuloma venereum, mouse pneumonitis, and meningo-pneumonitis); viruses of pox diseases (smallpox,

vaccinia, swine pox, etc.); the bacteriophage group; and viruses parasitizing plants. Each group is defined by reference to various criteria, such as host, antigenicity, modes of transmission, pathology, and susceptibility to sulfa drugs.

Although some viruses may be grouped according to similar characters, virologists are still more impressed by the constantly increasing heterogeniety observed in the properties of viruses, so that they may be thought of as being as varied and dissimilar as the wide range of bacteria.

(4) *Medical Mycology.*—Mycology has developed in relation to Bacteriology in two directions, namely, in the findings of antibiotics active against microorganisms and in the study of infections due to pathogenic fungi. Having already referred to the problems of range of bacterial antagonism, mode of action, drug fastness and biological assay, let us here mention the advances made in connection with antibiotic production itself: the discovery of new fungi elaborating the antibiotic principle, the choice of strains by careful test, the physiology of fungi, the factors affecting biological variation as exemplified by antibiotic production, purification and separation of the active principle, tests for and control of toxicity for host cells, development of media and procedures for commercial production, and the chemistry of the antibiotic preparations. Each point mentioned represents new, basic and practical advances pressed for war and scientific purposes, with results known and anticipated for the relief of suffering and the prolongation of life.

There occurs a disease in the dry regions of the Southwest due to a fungus, *Coccidioides immitis*. It seems to have its habitat in the soil or vegetation and when inhaled by man causes a condition which has not attracted much attention until our troops stationed in those parts for desert training became manifestly infected. This finding and the study of the fungus and disease have led to the recognition of the importance of the condition. Likewise, it has stimulated interest in other infections due to pathogenic fungi hitherto considered rare and unimportant. Such infections lead to a hypersensitivity to the proteins of the fungus and recently a large part of the young adult population in the Midwest has been found to be hypersensitive by skin test to the proteins of another pathogenic fungus, *Histoplasma capsulatum*. The significance of this finding is yet to be determined, but it does appear as though man even in the temperate zone possibly suffers generalized infections due to one or another fungus, in addition to the fungi that now are known to parasitize his skin, hair and nails.

These fungal infections, together with the opening field of antibiotics and the wide experience of our Armed Forces with mycotic conditions in the tropics, have served to stimulate much interest in mycology and already distinct advances have been made. Our chief lack of basic information in this field seems to be in the physiology of fungi, and we may look forward to developments in fundamental as well as in medical and industrial mycology.

To summarize, a few general remarks may be made. The basic science of Bacteriology is developing in many directions. There is no line of distinction between its various fields, nor between the diverse phases of the subject and other fields of science. Industrial and medical research in microbiology has been fundamental and abstract as well as applied, and, under whatever aegis, scientific advances have been mutually contributory. The distinction between so-called pure and applied science is fast fading if it has not indeed already disappeared.

Recent advances have contributed to another common principle, namely, the similarity of basic biological phenomena among the wide range of microscopic forms: metabolism in terms of enzymes and chemistry, cellular biology, chemical composition, parasitism, immunology, and reaction to external conditions.

If the two principal advances in Bacteriology were to be given, they might well be stated as the demonstration that scientific progress can best be made by a correlation of scientific approaches and the establishment of the common fundamental nature of the minute forms of life.

A REVIEW OR GASTROENTEROLOGY FOR 1945

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The literature on gastroenterology during 1945 was extensive. The various papers are particularly noteworthy because of the advances that have been made in diagnosis and treatment of many gastroenterological problems which arise in everyday practice. It is not my intention to include background on the subjects in this review because of the detail involved. The alimentary canal is usually discussed under separate headings, therefore it is deemed proper to group a summarical review in like manner.

ESOPHAGUS AND STOMACH

Esophageal varices have been shown to be much more common than was formerly suspected and are frequently the source of fatal hemorrhages. Patterson and Rouse (39) report a series of cases in which the varices were injected with a sclerosing solution even in the presence of hemorrhage. They maintain that only time will justify the conclusions drawn. It is their opinion that the results so far observed justify the procedure.

Clark (10) brings up the question of differential diagnosis between gastrointestinal conditions and cardiovascular disease. He points out that diaphagmatic hernia will frequently present a clinical picture resembling heart disease, particularly angina. He emphasizes that the symptoms of hiatus hernia are more apt to be associated with eating than with effort, and the pain is less promptly relieved with nitrates. He reminds us that gallbladder disease very frequently is found in association with coronary heart disease and in some instances the gallbladder will initiate attacks of angina. It is his belief that in selected cases the cholecystectomy may lessen or even clear up the attacks of angina. Feros (15) has presented an interesting study on the electro-cardiogastrographic test and its possibilities in differentiating various gastric changes. He points out the possibilities it offers in differentiating benign and malignant lesions in the stomach. It has been stated that the intra-gastric electrical conductibility can be influenced by changes in pH, changes in the gastric tissue and by general modifications of the total organism. Generally speaking Feros agrees with Bockus that a clinical evaluation of this procedure must await further study on a much larger group of cases. Others (26, 36, 46) in discussing the various diagnostic procedures in gastro-duodenal disease believe that the present methods of diagnosis are quite accurate with emphasis being placed on the history, x-ray, gastroscopy, gastric analysis and stool examination. Thorek (51) writes that in severe gastric disease involving the esophagus in which stability is a factor, gastrostomy should not be deferred until the patient's condition becomes critical. Too often the operation is considered only after the patient's condition is deteriorated by malnutrition and disease and at that time gastrostomy is attended by great operative risks and offers little benefit. Thorek believes that early operation tends to maintain nutrition and strength and frequently improves the condition of the esophagus by removing the irritation due to alimentation. In addition to this it may furnish information regarding the location and the nature of tumors in this region. One of the most important contributions that has been receiving considerable emphasis has been that of bilateral vagotomy for hypermotility and hypersecretion in gastric disease, particularly intractable ulcer. The supradiaphragmatic section of the vagus nerves, as described by Dragstedt and his associates (13, 52) conclusively shows that hypersecretion can be reduced and the motility likewise inhibited with marked clinical relief of the patient's symptoms. Roth and Ivy (19, 43) have

demonstrated experimentally that the stomach will still respond to caffein after bilateral section of the vagus nerves and they draw the conclusion that caffein presumably exerts its action peripherally on the gastric mucosa and not on a neurogenic basis. Gianelli and Bellaflore (17) have reported that an antiulcer factor called vitamin U has been shown to be effective in experimental peptic ulcer and they adopt the principle of giving their patients a liberal convalescent diet. This is of interest because of the recent advocation of the use of amino acids (32) and a high protein diet in the rapid therapy approach to ulcers. In addition to this, the use of tobacco was permitted. One of the newer drugs which has been described for use in hypermotility of the stomach is Dibutoline, which Peterson and Peterson (41) have shown is very similar to atropine and equally effective, but that the duration of action was shorter than for atropine. The advantage in using this new drug is that it has no cardiac effects and no mydriatic effect. They maintain that the margin of safety for this drug is very great and they have observed no idiosyncrasies. Ivy, Sandweiss and others (26, 45) present the interesting subject of the hormonal control of hypermotility and hypersection. Both of these groups have conclusively shown that there is an anti-ulcer factor contained in extracts from the intestinal mucosa, extracts of the urine of pregnant women and also certain pituitary factors. The active principle has been isolated and purified and they define the unit of the hormone to be that amount which will reduce by fifty percent the secretory response to one milligram of histamine in a twenty-pound dog with a pouch of the entire stomach. This has been found to be twenty milligrams of the active principle. It must be given intravenously because when other routes are used, for example, subcutaneously, the amount required is trebled.

LIVER AND GALL BLADDER

Two new tests for the determination of the presence of gallbladder disease have been described by Morrison and Swalm (34) which are predicated upon the determination of the specific gravity of the bile obtained from the liver and the gallbladder which in turn reflects their bile salt content. They observed that normally the specific gravity of gallbladder bile is greater than that of liver bile and in disease processes this ratio is disturbed. A new drug which offers some promise and has been marketed under the trade name Profenil has been described by Weiss (55) to be well tolerated and of low toxicity. It has been shown to abolish smooth muscle spasm irrespective of its origin, neurogenic or myogenic, and he predicts that in time it will replace papaverine and belladonna. The new drug may be given in tablet or hypodermic form.

Most of the gastroenterological literature for 1945 has been centered around the liver (5, 18, 23, 24, 25, 31, 40, 42, 48, 49, 56, 57) which deal with such conditions as amebic hepatitis and the necessity for early recognition particularly in those cases which develop pus and the rather prompt response which is obtained with emetine; infectious hepatitis and its relationship to homologous serum jaundice and post-vaccinal hepatitis. It has been shown, in regard to the latter three conditions, that one and the same factor are presumably concerned and the only difference is in the mode of transmission. One outstanding fact in regard to virus hepatitis is the necessity for prolonged bed rest and the question of recurrence following too early ambulation. Biopsy studies in many cases have shown the consistent finding of necrosis and in a very small percentage of cases have led eventually to cirrhosis. From a diagnostic standpoint the tendency has been to develop a series of rapid tests that can be done expediently and inexpensively (14, 18, 21, 33, 37, 38) the most notable of which have been the modification of the Harrison's test for bilirubin in the urine and the quantitative determination of the serum bilirubin according to the methods developed by Ducci and Watson (14). This latter test has its greatest value in the differential diagnosis between obstruc-

tive and toxic jaundice. The crux of the newer methods of technique and interpretation is based on the fact that the quantitative prompt bilirubin is low in toxic (hepatic) jaundice, and high in obstructive jaundice. Two new papers have appeared (1, 44) on the determination of vitamin A in liver disease and the utilization of a vitamin A test meal to show the hepatic response in health and disease. Aldersberg (1) and his associates maintain that the normal fasting level of vitamin A varies from 40 to 100 micrograms percent. In severe liver disease this falls to levels of 20 or 30 and following a test meal, normally peaks of up to 276 micrograms are reached, whereas in hepatic disease there is no response. An additional note in regard to Atabrine and its effects on the liver, Butt (8) states that the toxic effects from this drug are few and far between and that its use in malaria is relatively safe because of this fact. Bauer (3) points out that cholinesterase can be demonstrated in serum. He has found that in liver disease the values for this substance are markedly lowered and that it is a relatively sensitive test. Hines and Kessler (22) report that penicillin produced extensive hemorrhages in two of their patients who had received the drug for bacterial endocarditis and the cause is presumably that penicillin increases the sensitivity to heparin. Havens and Paul (20) demonstrated that the intramuscular injection of gamma globulin was effective in preventing the spread of infectious hepatitis. From a theraupetic standpoint Darmady (12) supports other authors (Wade, Jolliffe, Alpert and Barker, 2, 29, 53) in the rather generally accepted observation that large amounts of protein are of primary importance in the treatment of hepatitis as a result of infection and also cirrhosis due to any cause. In addition to the use of a high protein dietary supplement, Beams (4) has reported that choline and cystine are of great value in treating cirrhosis in the hypertrophic phase. Cartwright and Wintrobe (9) support Watson and Castle (54) that choline in the treatment of cirrhosis of the liver has no deleterious effect on the blood picture. In a study of a series of patients with pernicious anemia, Boyden and Layne (7) found that the incidence of gallbladder disease was higher in this type of case. Bennett (8) in discussing the possible etiological factors in the development of disturbed protein metabolism predicates the hypothesis that the responsible factor is an absence of the methyl group and its relation to the sulfur-containing amino acids. She summarizes the complex chemistry by saying that an adequate supply of preformed labile methyl groups is necessary for normal growth and that this methylation factor presumably is based upon bacterial flora in the bowel and the ability of the liver to make use of these various chemical compounds resulting therefrom.

INTESTINAL TRACT

Isaacs (27) states that until 1944 only 127 adenomas of the pancreas had been reported, and the fact that these patients must be differentiated from those having malignant tumors of the pancreas. He points out that the biggest difficulty is in locating the tumor and surgically removing it with a resultant excellent chance for complete recovery from the hyperinsulinism.

Darby, Jones and Johnson (11) report on the use of L. Casei factor in sprue and they propose that the group of substances related to L. Casei factor and folic acid be termed the vitamin M group. Kiefer and Ross (30) state that their experience with 102 cases of chronic ulcerative enteritis has been that conservative management is advisable in the acute forms of the disease, and also in the mild cases of chronic uncomplicated terminal ileitis. However as a general rule these authors state that in the chronic stage the best method of therapy is surgical resection. An interesting commentary by Most (35) to the civilian physician is his emphasis of the use of zinc sulfate flotation of stool specimens as a practical and efficient method of detecting the majority of the various intestinal parasites, particularly those found in persons who have been in the armed services and are returning to this country from military duty. Smith (47) in discussing Shiga dysentery points

out that a diagnosis by proctoscopy is possible within twenty-four hours after the onset of symptoms. In his series of cases 47 percent had negative stool cultures and the diagnosis might have been missed if direct visualization of the colon had not been done. He emphasizes that the golden opportunity for effective treatment occurs in the first twenty-four hours and that at this time the diagnosis can only be made in many instances by proctoscopy. Sokoloff (50) reports that chronic amebic infection responds very satisfactorily to anhydrous lactic acid and in some instances better results are obtained when combined with iodine.

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RECENT ADVANCES IN PHARMACOLOGY AND MATERIA MEDICA

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Any brief report on the present status of pharmacology involves the careful selection of those topics which seem to be of major importance, and even these must be treated somewhat cursorily. I have, therefore, chosen to divide this report into two sections; the first dealing with the present status of, and the future outlook for, the chemotherapy of infectious diseases, and in the second section to discuss miscellaneous advances in divergent areas.

In dealing with the present status of chemotherapy, the discussion can be conveniently divided into two phases: (1) the sulfonamides, and (2) the ever-increasing group of substances derived from living organisms and ambiguously called "antibiotics." Of the ten or twelve clinically useful sulfonamides which have been developed over the last ten years, it seems safe to say that at the present time only one of these—sulfadiazine—need be given serious consideration. It is generally recognized that when a sulfonamide is indicated sulfadiazine should be the drug of choice The only serious exception to this general statement would be in the case of those sulfonamides, represented by sulfasuxidine, which are not absorbed, and which have a certain limited usefulness through their local action in the gastro-intestinal tract.

There have been no new developments in the case of sulfadiazine, but certain factors involved in its clinical application have become more clearly defined. Among these, the following are worthy of note:

(1) Clinical effectiveness following systemic administration is equal or superior to that following local application.
(2) The efficiency of sulfadiazine prophylaxis has been definitely established, particularly in those diseases caused by the hemolytic streptococcus. Prophylactic use must, however, be balanced against:
(3) The increasing incidence of patient sensitivity to the drug and the development of strains of sulfonamide-resistant organisms;
(4) And finally, it seems possible to predict, on the basis of physico-chemical studies, that other substitutions of the basic sulfonamide nucleus will not produce drugs which will have any greater therapeutic effectiveness than does sulfadiazine.

Available data in the field of antibiotic research are undoubtedly incomplete, but it seems certain that some 50 to 75 antibiotic substances have been partially or completely isolated and are in various stages of investigation; however, only two—penicillin and streptomycin—can be said, at present, to have widespread clinical importance.

Penicillin is now available in adequate quantities, although the supply is not unlimited and precludes, for the time being at least, any widespread application of unproven methods of administration. The concensus among clinical investigators is that for maximum effectiveness penicillin must be administered parenterally. There is, as yet, too little clear-cut experimental or clinical evidence to enable one to predict the possibilities for the oral administration of penicillin. Herein lies a major difficulty in penicillin therapy. In most instances, the physician will feel that the patient must be hospitalized before he is given penicillin. This is to insure the all-important factor of maintaining adequate blood levels by means of controlled day-and-night administration. The choice between sulfadiazine and penicillin in the management of disease produced by susceptible organisms is, of course, determined primarily by the susceptibility of the organism in question to

each drug. Where either drug will satisfactorily combat a given organism the choice frequently hinges on the difficulties encountered in administering penicillin.

The special cases of syphilis and gonorrhea require separate mention. It must be emphasized that the use of penicillin the therapy of syphilis is as yet in the experimental stage, and will retain that status until sufficient time (2–5 years) has elapsed to permit the proper evaluation of results. It is not possible to state definitely whether penicillin alone or in combination with heavy metals will significantly advance the therapy of this disease. In the case of gonorrhea two factors must be recognized. The first of these is the extraordinary susceptibility of the gonococcus to many forms of therapy, and its equally extraordinary ability to develop resistance to any given therapeutic agent. Penicillin-resistent strains of gonococci have been reported, and it is as yet too early to predict the final status of this agent in the therapy of gonorrhea.

The second factor which must be recognized is the possibility of the simultaneous occurrence of gonorrheal and syphilitic infection with the latter in its innocuous primary stage being masked by the earlier clinical onset of gonorrhea. Under such circumstances, superficial healing of the unrecognized primary chancre may occur with the dosage of penicillin used to treat gonorrhea. This quantity of penicillin is grossly inadequate to ensure the destruction of all the spirochaetes and the patient is thus exposed to the possibility of developing treatment-resistant syphilis and to the hazards accompanying the inadequate treatment of this disease.

The clinical usefulness of streptomycin is still in the process of evaluation. The quantities available at present are too small to permit extensive controlled investigation. In general, streptomycin is effective against many gram-negative bacilli, whereas penicillin is ineffective, and the sulfonamides have only limited usefulness in infections caused by these organisms. The effect of streptomycin in controlling three diseases—brucellosis, tularemia, and typhoid fever—hitherto unaffected by chemotherapeutic agents has received considerable attention recently. At the present time the outlook for its usefulness in the treatment of tularemia is good; in combatting brucellosis, less than fair, and for typhoid fever, poor.

Even less can be said about the effectiveness of streptomycin, or any other chemo-therapeutic agent for that matter, in the treatment of tuberculosis. At the present time no optimism is justifiable.

No report of the present status in the field of chemotherapy would be complete without mention of the enormous possibilities which have been opened to investigators by the elucidation of the mechanisms of action of the agents just discussed. All of them are effective by virtue of the fact that they interfere with some essential metabolic activity of the organism. The application of this basic principle renders possibilities for the control of infectious agents virtually unlimited.

Of the host of advances which have been, or are being, made in other areas, time permits the mention of only three:

Thiouracil—This synthetic pyrimidine derivative possesses the unique property of inhibiting, in a manner not entirely clear, the production of the thyroid hormone. This activity had led to the use of thiouracil in the control of hyperthyroidism. However, its place in the general management of hyperthyroid patient has not yet been satisfactorily evaluated. It seems clear at the present time that thiouracil may not be depended upon to control completely such a patient, but that it must be used in conjunction with other procedures, including surgery. Its use is attended by a fairly high incidence of toxic reactions, the most alarming of which is agranulocytosis. This toxicity could conceivably lead to its abandonment as a therapeutic agent, but only time and wider clinical experience will determine this possibility.

Benadryl—It is a well recognized fact that histamine plays a very large part in the production of those lesions which characterize allergic reactions of all kinds. A long-held theory has supposed that if some substance could be found which

would antagonize the action of histamine it should be possible to relieve or prevent the manifestations of allergic disturbances. Benadryl seems to be such a compound. It is by no means a panacea for all types of allergic disturbances, but it seems to be outstandingly effective in providing symptomatic relief in angioneurotic edema, allergic rhinitis, and allergic bronchospasm. The drug does not affect antigen-antibody relationships or formation, and in this respect represents a purely symptomatic approach to a very complex problem.

Digitalis—It would be misleading to confine a review of recent advances to new drugs exclusively. Both clinical and experimental pharmacologists devote a large share of their time and effort to the improvement of therapeutic agents of known values. The gain which has been made in the direction of a more complete understanding of the chemical characteristics, the mechanism of action, and the rational clinical application of the digitalis bodies represents an outstanding example of this type of continuing progress. Until very recently the infinite complexity of digitalis in all its relationships has made the crude leaf the preparation of choice, and the oral route the only reliable method of administration. There is now, however, reason to believe that the limitations and uncertainties imposed by this combination may be overcome. More refined chemical techniques and more accurate and detailed pharmacological observations have resulted in the isolation, identification, and use of the active glycosides of digitalis in pure, unaltered form. Two of these compounds, digitoxin and digilanid C, are especially worthy of mention. They are receiving widespread clinical trial, and the reports on their effectiveness are very encouraging. This trend, supported by continually accumulating data, permits the prediction that the pure glycosides may eventually supplant the crude leaf, and it is very probable that their use will materially enhance our ability to control cardiac failure and, at the same time, increase our knowledge of the abnormal physiology of the failing heart.

RECENT ADVANCES IN AVIATION MEDICINE

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In any attempt to review recent advances in Aviation Medicine, one must remember that almost all aviation medicine is recent. Although a not inconsiderable amount of experimental work was done during the first World War, nearly all of this work was discontinued shortly after 1918, and much of the material that had been studied and investigated was forgotten.

In marked contrast to the policy followed in Germany and Russia, where the subject of aviation medicine was continuously and actively investigated, this subject was completely neglected in the United States. Therefore our entry in the late war made it necessary for us to establish a multitude of laboratories and to carry on our investigations with almost feverish haste in order that we should not be hopelessly outdistanced by the Axis.

In a brief review such as this, it is obviously impossible to adequately cover the entire field. I have, therefore, somewhat arbitrarily selected three different sub fields in each of which outstanding results have been reported during the past year or two.

First, I want to take up the subject of angular acceleration or centrifugal force. If a fighter pilot is diving at the rate of 450 miles an hour and pulls out of this dive on the arc of a circle having a radius of about one-half mile, centrifugal force will press his body down onto the seat of the plane with a force which will be slightly more than five times the force of gravity. Thus if the flyer's weight is 180 lbs., the

force of his body against the seat of the plane would equal more than 900 lbs. His arms would be so heavy that he would be unable to lift them. The blood would have a weight five times its normal value. This would make it difficult for the heart to pump an adequate amount of blood to the brain. Blood would, therefore, tend to drain out of the upper part of the body and become pooled in the abdomen and the legs, and the aviator would suffer from cerebral ischemia. The first effect of this ischemia would be a blurring and graying of the vision as though a semi-transparent curtain were lowered before the eyes. This would be accompanied by a narrowing of the visual field. If the centrifugal force on the body is continued or increased, the aviator will "black out," that is, he will suffer a complete loss of vision and finally will lose consciousness. The extent of the physiological changes produced depends upon both the magnitude and duration of the centrifugal force applied to the body. Most young normal individuals can tolerate a centrifugal force as great as four to five G. for a period of as long as five to ten seconds.

One of the problems of aviation medicine has been the development of devices for protection of aviators against these effects of centrifugal force. So far the most successful device of this sort developed is the so-called arterial occlusion suit, of which you have probably read in the newspapers. This consists of a suit into which are incorporated three inflatable elastic bandages; one across the abdomen and one around each of the thighs. When the aviator performs any manuever which involves increased centrifugal force, these bandages are automatically inflated in such a way that pressure is exerted on the wall of the abdomen and on the large arteries in the thighs. This pressure constricts or occludes these arteries, with the result that the blood is prevented from pooling in these parts. This means that more blood is retained in the upper part of the body and the aviator's tolerance of centrifugal force is increased. However, there is a definite limit to human tolerance of centrifugal force even with the best protective devices. This limit is on the average about 7 G.

The second development which I wish to discuss is the equipment for what is known as pressure breathing. It is well known that at altitudes of more than 15,000 feet men find it difficult or impossible to live and carry on ordinary activities because of oxygen lack. This lack of oxygen is not the result of any decreases in the percentage of this gas in the air, but rather of a lowering of the oxygen tension as a result of the decrease in total barometric pressure. It is quite obvious that protection against this anoxia of altitude can be obtained by breathing oxygen enriched air. Thus a person breathing 100 per cent oxygen at an altitude of 35,000 feet, where the barometric pressure is a little less than 100 mm. Hg. would be just as well off in regard to his oxygen supply as though he were breathing air at ground level. However, if he goes up to 40,000 feet, even breathing 100 per cent oxygen the alveolar oxygen tension would drop to about 55 mm. Hg. and his arterial oxygen saturation would be down to something under 80 per cent. He would, therefore, be in a precarious situation and on the verge of losing consciousness. It is generally stated that 42,000 feet is the absolute ceiling for the most resistant aviator, even when he is breathing 100 per cent oxygen.

During the latter part of the war, oxygen equipment was developed which delivered oxygen to the lungs of the aviator at a pressure of slightly greater than that of the ambient atmosphere. This results in an increased alveolar oxygen tension and makes it possible for the aviator to go a few hundred feet higher than he would otherwise be able to do. Two sorts of pressure breathing equipment have been developed: first, the constant pressure type in which the increased pressure is maintained continuously and second, the intermittent type in which the increased pressure is applied only during inhalation. Breathing is a little easier with this type of apparatus, but it is more complicated and therefore more likely to get out of order.

And now we come to the pressurized cabin and the problem of explosive decom-

pression. Even before the war the pressurized cabin was beginning to come into use as a means of protecting passengers in aircraft against the unpleasant effects of decreased barometric pressure. This mechanical development was carried to a much higher state of perfection during the war and as everyone knows, was a not inconsiderable factor in the success of our long distance, high altitude bombers. The pressurized cabin, of course, is the ideal solution to many of the problems of high altitude flying. But as is so often the case, the solution of one problem pushes to the forefront other as yet unsolved problems. Thus with the pressurized cabin in common use, the problem of explosive decompression became one of paramount importance. If a bomber is flying at an altitude of 35,000 feet where the barometric pressure is 180 mm. Hg., with the pressure inside the cabin at 560 mm. Hg., the crew would be subject to the hazard of an extremely rapid drop in barometric pressure in case of a large caliber shell piercing the cabin. Under these circumstances, the barometric pressure in the cabin might drop as much as 380 mm. Hg. (one-half atmosphere) in a fraction of a second. This is a pressure change of 7½ lbs. per square inch. At first thought one would be inclined to feel that human beings could not tolerate such rapid and extensive changes in barometric pressure. In the early days of the war, explosive decompression was considered an extremely serious hazard. It became necessary that we should know what the tolerance of human beings was to such rapid changes in pressure and also what harmful effects might be expected to result. Here in our Ohio State laboratory, we began investigating these problems in January, 1942. We developed a technique for producing explosive decompressions at a rate which was equivalent to going from ground level to 50,000 feet in .02 of a second. Various species of animals were subjected to such explosive decompressions and to our surprise there were no harmful effects. A few minor hemorrhages of the lungs and occasional small hemorrhages in the ventricle of the brain were the most serious effects produced. None of these was of such a nature as to seriously incapacitate the animal. In fact, experimental animals showed complete recovery from such minor lesions in a period of two or three days. The only serious hazard seemed to be the possibility of the extreme expansion of the gas trapped in the stomach and intestine. At 40,000 feet, a gas would occupy a volume five times as great as that occupied at ground level. This means, of course, that when the gas is trapped in a confined space in the body, considerable pressure might be developed. We found that herbivorous animals, such as guinea pigs and rabbits, that are known to have considerable amounts of gas in the gastrointestinal tract, occasionally died following explosive decompression as a result of ruptured stomachs. In no case, however, did any of the dogs or cats which we used suffer serious injuries from explosive decompression.

We investigated in some detail the physiological effects of such rapid changes in barometric pressure. As would be expected, we found that there was a momentary but rather marked increase in the intrathoracic pressure. This is, of course, caused by the fact that the expanding air in the lungs is unable to escape through the trachea at a rate sufficient to keep pace with the fall in the ambient pressure. In other words, the lungs decompress at a slower rate than does the experimental chamber or the cabin of the aircraft. This rise in intrathoracic pressure is, we believe, the fundamental cause of all other physiological changes that take place following explosive decompression. Among these effects is a rise in the cerebrospinal fluid pressure. While our experiments on this point cannot as yet be considered final, such data as we have seem to indicate that the rise in cerebrospinal fluid pressure parallels, both in extent and duration, the rise in intrathoracic pressure. We also found a marked slowing of the heart and a drop in blood pressure. The slowing of the heart occurs immediately following the explosion. The drop in blood pressure begins after a delay of perhaps a second or so. This drop in blood pressure is probably due, at least in part, to interference with the venous

return to the heart by the increased intrathoracic pressure. There are also undoubtedly reflexes involved. Cardiac slowing seems to be solely of reflex origin since it is abolished by bilateral vagotomy. Our work on animals was followed by many experiments with human subjects. In general these experiments verified the results which we had previously attained with animals, although of course there were many things that we had done with animals that it was impossible to do with men. Furthermore we have never subjected our human subjects to the extremely rapid decompressions used with animals. We have shown, however, that explosive decompression is not a serious hazard to aviators.

In this short paper I have not attempted to give credit either to individuals or to laboratories for developments which I have mentioned. They were all cooperative undertakings in which a number of laboratories participated. It must also be borne in mind that there have been many other developments which were no less important than those I have discussed, but time does not permit further elaboration of the subject.

RECENT ADVANCES IN PHYSICAL MEDICINE

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The field of physical medicine is expanding very rapidly and with such development is demonstrating its value in a broad and neglected phase of medicine as practiced today.

The Council on Physical Medicine of the American Medical Association defines physical medicine as including the employment of the physical and other effective properties of light, heat, cold, water, electricity, massage, manipulation, exercises and mechanical devices for physical and occupational therapy in the diagnosis and treatment of disease.

Physical Medicine is developing and progressing into three major fields: (1) physical therapy and the employment of physical agents in diagnosis, (2) occupational therapy with the usual arts and crafts plus the wider field of pre-vocational, avocational, and vocational pursuits, and (3) reconditioning of the convalescent patient which includes not only physical training but also the provision of educational and recreational programs as developed by our military services during this past world war to utilize the period between definite care and ability to return to productive work; thus shortening convalescence and obtaining maximal functional recovery.

In 1944 the Baruch Committee on Physical Medicine was initiated by the grant of Bernard M. Baruch to advance and encourage research, teaching and training in the field of physical medicine. The general research and training projects were formulated as follows:

(1) To develop both medical and technical teachers of physical medicine in the basic sciences and clinical aspects of physical medicine.

(2) To investigate the problems of hydrology, climatology and spa therapy.

(3) To study the prevention and manipulative aspects of the structural mechanics of the human body.

(4) To study and develop electronics and other physical agents because of their increasing importance in physical equipment which could be employed in research as well as in clinical application of physical medicine.

(5) To promote special clinical investigation of the psychologic and psychiatric aspects of physical medicine.

During the past year, grants were made to a number of medical schools and Dr. Frank H. Krusen, medical director of the Baruch Committee, has summarized the projects at the specific institutions as follows:

(1) Columbia University, College of Physicians and Surgeons—Research projects dealing with insulin therapy in combination with fever therapy produced by physical means; studies of electric shock therapy; the effect of temperature on hemorrhage, fluid, and electrolyte balance; distribution of volume of blood, and metabolic disturbances resulting from circulatory changes; basic problems of circulation in small vessels and capillaries; the use of radioactive isotropes in circulation investigations.

(2) Medical College of Virginia—Study of birefringence of mammalian muscles; changes in muscle proteins during atrophy; use of electrical stimulation, massage or baths to overcome atrophy.

(3) Massachusetts Institute of Technology—Investigation of the dielectric properties of muscles and tissues in high frequency fields and nerve impulses by electronic methods.

(4) Harvard University—Study of biochemical factors relating to fatigue and the psychiatric aspects of fatigue in psychoneurotic patients.

(5) University of Southern California—The evaluation of compensatory action in muscles or muscle groups; the use of soft tissue x-rays and metal pin implants to study muscle movement; the determination of electrical potentials in muscular contractions; the interruption of neuromuscular pathways by pressure, nerve section and chemicals; the effects of internal environment on regeneration of neuromuscular pathways and return of function.

(6) University of Iowa—Research in the use of thermogenic agents on deep tissue heating, and the effects on circulation of short wave diathermy in animal experiments.

(7) Marquette University—The effects of temperature changes on the neuromuscular apparatus with special reference to thermal shock.

(8) Washington University—Research program on body mechanics.

Laboratory research in electrodiagnosis, electromyography, and low frequency muscle stimulation has been a prominent investigative field.

In studies on peripheral nerve lesions, electrodiagnosis by means of a progressive current of long duration has shown great prognostic importance. A progressive current is one which increases with time and in peripheral nerve lesions, there is a progressive diminution in threshold amperage until the period of denervation is reached. With recovery, there is a rise in threshold amperage. These electrical signs of recovery precede clinical evidence of motor and sensory recovery often by months.

In a like manner, electromyography is of diagnostic aid in similar peripheral nerve lesions. No electrical activity can be recorded from normal relaxed voluntary muscle, although it is always present when there is action in muscle tissue. In practically denervated muscles, fibrillation action potentials can be obtained. During re-innervation, fibrillation action potentials decrease. In detecting small degrees of nerve interruption, electromyography is of particular value. It also helps in placing the level and extent of lower motor neuron lesions since the amount of denervation can be assessed. Thus work in electrophysiology and electropathology has resulted in the recording by suitable needle electrodes, the action potentials of muscles. To date such methods are chiefly used in laboratory studies but a definite clinical use is in the making.

The relation of Physical Medicine to Psychosomatic Medicine has been emphasized in the use of electric shock therapy in the various psychoses. Electric shock is the most easily administered shock therapy and the results are comparable to those of insulin and metrazol. As in other forms of shock therapy, only the existing mental state is altered. There is no change in the prepsychotic personality and other forms of psychotherapy are essential.

The combination of physical and drug therapy in the forms of fever-chemotherapy and of ion transfer has developed further.

Studies have been continued in the use of artificial fever and chemotherapy in early syphilis in the hope to obviate the necessity of long courses of either chemotherapy or of fever-chemotherapy. Valuable data has been obtained on such combinations during this past World War.

Ion transfer with histamine and novocain has been used extensively in recent years. Irritation of the skin and underlying parts has been used more or less successfully in the treatment of aches and pains due to soft tissue involvement. Pronounced analgesic action is probable directly due to improved circulation which relieves tension in subfascial spaces and removes toxic products. Histamine ion transfer is one of the simplest and most effective counterirritant measures available. In cases of painful limited joint motion, novocain ion transfer is very effective with complete relief of symptoms plus surface analgesia for three to four hours.

Continued studies using hypotheramy further corroborated its uses for surgical anesthesia, preservation of poorly nourished tissues, treatment of infection and shock, and treatment of burns. Preliminary observations on selective destruction of superficial tumors by temporary local asphyxia using carbon dioxide ice have proven the feasibility of this method.

Ultraviolet irradiation plus the use of fluorescein has been used with success in determining the viability of strangulated intestine as well as in the establishment of diagnosis and prognosis in peripheral vascular diseases. When fluorescein is injected intravenously, it can be made visible by a beam of ultraviolet radiation on reaching any area of exposed skin or mucous membrane by the blood stream. In cases of damaged bowel, the presence of fluorescence has been shown to be sufficient evidence of viability. The postoperative course and pathologic sections have borne out the prognosis based on this method and so has removed the usual uncertainty incidental to such cases.

For years there has been a need for a means of estimating heat radiation in clinical practice. Recently there has been developed an experimental instrument, a thermoradiometer, which can be placed in the patient's skin and directly measure the radiation flux. It is hoped that a simple clinical recording instrument that will allow more accurate estimate of administering heat radiation will be an outgrowth of these experiments.

Laboratory experimentation with microwaves and supersonics as well as with the cyclotron and atomic energy have indicated that it is within the range of definite possibility that the therapeutic use of these powerful new forms of physical energy may bring far-reaching developments. Radioactive sodium as prepared by means of the cyclotron has already been used as a tracer substance in the blood in the study of patients with peripheral vascular disease. Thus the past few years have shown progressive advances of sound large scale developments in physical medicine.

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RECENT ADVANCES IN MEDICAL GENETICS

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The most spectacular, if not the most important advance in medical genetics in recent years has been the unraveling of the complexities of the blood agglutinogens. Fourteen such agglutinogens are now known, and a fifteenth is postulated and will doubtless soon be described. These antigens in various combinations form the so-called human blood groups and types. Not many years ago we spoke of four blood groups. Today we know 5,760, and we will soon be able to distinguish 8,640, when the last of the three Hr antigens is identified.

The various medical and medico-legal problems centering around the blood groups are fundamentally problems of medical genetics, and can be solved only by modern medical genetic methods. The individual agglutinogens are inherited as dominant factors, some of them related as alleles of a series, others independent of each other in inheritance. In the A–B series there are now eight groups, by virtue of three sorts of A antigen. They are as follows: O, A^1, A^2, A^3, B. A^1B, A^2B, A^3B. In the M–N series there are five types, namely, M, N^1, N^2, MN^1, MN^2. Since any one of the eight in the A–B series could be any one of the five in the M–N series, there are 8 × 5, or 40 groups in these two series combined. In the P. series there are four types, P^1, P^2, P^1P^2, and P−. This makes 40 × 4, or 160 groups. Since any one of these may contain antigens in water-soluble form (secretors) or in alcohol-soluble form (non-secretors), there are now 160 × 2, 320 groups. The recently-discovered Rh antigens are combined into eight types, Rh^{o}, Rh', Rh'', $Th^{o\prime}$, $Rh^{o\prime\prime}$, $Rh'{}''$, $Rh^{o\prime}{}''$ and Rh−. These, added to the list, make 320 × 8, or 2,560.

The newest of the agglutinogens are the Hr factors. These are not independent of the Rh antigens, but are reciprocally related to them, so that we must redescribe the Rh group by adding an Hr designation to them. At present we can identify Hr' and Hr'', and no doubt soon will have identified Hr^{o}. Using all three Hr factors, there are 27 Rh–Hr groups. Multiplying these 27 by the 320 groups which we identified without the Rh–Hr antigens, we have 320 × 27, or 8,640 human blood groups.

These groups are all of use in medico-legal cases of disputed paternity, and in the identification of individuals, but only the A–B series and the Rh–Hr series are of practical importance in transfusions. The A–B groups are involved in transfusions because certain individuals contain natural antibodies against agglutinogens A and B. The Rh–Hr groups are of importance for another reason, for, although no natural antibodies against these antigens are ever present as far as we know, antibodies can be produced against them when they reach the blood stream of a person lacking them. Thus in multiple transfusions Rh− blood must be given to an Rh− person.

The most important application of the Rh antigens is in pregnancies where an Rh− woman caries an Rh+ fetus. Here the antigen of the fetus may pass through the placenta into the mother, immunizing the mother. The resulting antibodies may return through the placenta and unite with the Rh antigen of the embryo, causing one or another of the manifestations of erythroblestosis (Levine, 1943; Wiener, 1943, 1945).

The Rh antigen of the embryo is of course inherited from the father in these cases. The father is, therefore, Rh+. He may be homozygous (pure) for the Rh factor, or he may be heterozygous and carry the gene for Rh−. In the first instance all his children will be Rh+, in the second, only half. As a rule the first Rh+ pregnancy serves merely to immunize the mother, while a second or later Rh+ pregnancy stimulates the further rapid production of antibodies, which may then affect the embryo. Occasionally a first Rh+ child is affected, and we have some evidence in our laboratory that these affected first-born children show spina bifida and other gross abnormalities. In some instances affected first-born children may be the result of a previous transfusion given to the mother.

When we determine by genetic methods how often by chance an Rh− woman would be expected to marry an Rh+ man and to produce an Rh+ child, we run into some interesting facts. In a population such as that of the United States we would expect 28.8% of all children born to have one or another Rh antigen which the mother does not have. If all such cases are potentially erythroblastotic, we should expect the incidence of erythroblastosis to be 28.8%. However, the frequency of clinically diagnosed cases has never approached this figure. The recorded incidence is about one in 200 births, or about one-half of one percent. Obviously the difference between 28.8% and one-half of one percent is a discrepancy which must be explained.

First of all it has been observed that of the three Rh antigens, only Rh^{o} is of any great importance in producing symptoms. There have been a very few cases reported of effects due to immunization with Rh' or Rh'', but the number is relatively insignificant. We may confine our attention, then to Rh^{o}. When we compute how often a child will be expected to have Rh^{o} when the mother lacks it, we find the answer is 8.7%. This is much closer to the observed half of one percent, but still far enough away to demand further investigation.

Next we recall that first-born children are seldom affected. In our American population about 31% of children are first-born. Eliminating these from our calculations, we would expect 6% of children to have Rh^{o}, to be born of mothers lacking Rh^{o}, and to be second- or later-born in the family. This further closes the gap between the expected and the observed incidence of symptoms due to Rh immunization, but still leaves a discrepancy.

Looking further, we see that the cases of erythroblastosis are not distributed randomly among the Rh− mothers, but are grouped into specific families. This suggests that the Rh^{o} antigen may permeate the placenta only in certain Rh− mothers, or that perhaps only certain Rh− women are capable of producing potent antibodies. It may be that both these things account for the fact that not as many cases of erythroblastosis are found as can potentially occur.

Another intriguing possibility suggests itself, and the exploration of this possi-

bility has led to suggestive results. It is conceivable that in some instances where the antigen immunizes the mother, and the antibody in turn reaches the fetal circulation, that the effects on the fetus are different from those usually recognized as classical erythroblastosis.

Following the lead of Yannett and Liebermann, we have investigated the possibility that Rh immunization might in some instances result in feeble-mindedness. Our results confirm this, and we tentatively suggest that this finding raises the incidence of effects from one-half of one percent to one percent, thus closing the gap further.

Still another genetic factor may be involved in the recent discovery by Wiener that immunization may result in either of two kinds of antibodies, univalent or bivalent. The manifestations may depend upon the kind of antibody produced.

In addition to the practical applications of the blood agglutinogens, which have taken up an undue proportion of this review, applications in prevention, in diagnosis, and in genetic prognosis have developed from modern medical genetic research. For examples of these, see Snyder, 1946.

Fundamental research on which such practical applications are built has progressed rapidly in recent years. The basic relations of the mutant gene in man have been thoroughly investigated. A new type of hereditary transmission, incomplete sex-linkage, has been added to the longer-known types (Haldane, 1942), and this has made possible the first chromosome maps for man.

Recent studies with the electroencephalograph by Lennox and his co-workers have shown that cerebral dysrhythmia is inherited as a dominant factor, and may be used in predicting the occurrence of epilepsy in families. The genetic aspects of human cancer have been thoroughly reviewed and documented by Blank (1944).

The biochemistry of several human anomalies has been worked out, and tied in with genic action. Thus a single gene controls the production of an enzyme which, when present, brings about a certain reaction, but when absent, fails to bring about the reaction. Mutations in single genes thus bring about, through failure to produce the appropriate enzyme, albinism, phenylketonuria, alcaptonuria, Von Gierke's disease, and other errors of metabolism. The enzyme, its point of action, and its genetic determiner can now be exactly specified (Haldane, 1942; Beadle, 1945).

Lethal factors have been investigated, and various rare human anomalies which were long thought to be simple dominant factors have been shown to be lethal in the homozygous condition (cf. Snyder and Doan, 1944). These dyscrasias include telangiectasia, minor brachydactyly, sebaceous cysts, spina bifida and Pelger's anomaly.

For a comprehensive review of the recent advances in fundamental research underlying medical genetics, see Muller, Little and Snyder (1946). For text books on medical genetics, there are recent editions available by Roberts (1940), Davenport, Keeler, Slye and Macklin (1940), Snyder (1941), Ford (1942), Gates, Snyder and Hooton (1943) and Bauer (1945).

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THE HAZARDS OF TROPICAL DISEASES AS A RESULT OF WORLD WAR II

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Serious consideration was given throughout the war to risks of introducing exotic diseases and other harmful agents into the United States through the traffic of war and the return of military personnel from abroad. Estimates of hazard varied widely, but the most critical epidemiological analyses anticipated little risk in most instances. This was the viewpoint also of the Interdepartmental Quarantine Commission jointly established by the Secretaries of War and Navy and the Administrator of the Federal Security Agency to study this problem. Precautions recommended by the Commission were established in special quarantine programs of the Armed Forces.

With the end of fighting and return of the bulk of combat forces, it is now possible to review actual results on a preliminary basis. Optomistic conclusions appear warranted though tentative. No acute outbreak or secondary spread of non-indigenous disease has been reported to date in the United States and while more slowly evident infections may yet be identified it must be remembered that traffic and return have now gone on for four years.[1]

Malaria has always received priority consideration among risks to the public health of this country as a result of the war. Aiming primarily at maintenance of fighting efficiency, the Army and Navy greatly emphasized prevention and suppression of this disease. Though malaria remained the commonest infectious disease of troops abroad, the 460,000-odd reported hospitalizations of Army

[1]Subsequent information requires revision of this statement. One soldier who arrived in San Francisco by air in patient status for neuropsychiatric disease on 28 December, 1945, in the incubationary stage of smallpox is considered the starting point of infection for six subsequent civilian cases. The mode of first secondary infection is uncertain but apparently indirect. Two other military cases arrived at this port in patient status because of smallpox on 29 March and 8 April, 1946; no apparent secondary infections occurred. In Seattle a diagnosed case of smallpox entered in patient status on 5 February, 1946, and was hospitalized immediately. The first secondary case was a patient in that hospital, vaccinated on 6 February with a primary reaction, whose smallpox began on 16 February. Most of the remainder of 40 cases which occurred in Seattle seemed traceable to this second person; routes of infection in the remainder were uncertain. In Los Angeles a diagnosed case of smallpox entered 28 January, in patient status; no secondary infection occurred. A Customs official in San Diego was diagnosed as having smallpox about 5 March, 1946; no definite source was determined and secondary cases did not occur.

personnel from the onset of war through December, 1945, are far below pessimistic anticipation. As this figure includes both initial and recurrent infections, the total of persons involved was appreciably smaller.

Malaria is not susceptible to practicable border quarantine, and prolonged detention of returning personnel in segregation areas to avoid dissemination of the infection among the general populace was deemed unfeasible and unnecessary. Considering that only a portion of persons infected abroad are liable to recurrence after return to the United States (about 60,000 military hospitalizations to 1, July, 1945) and that these will be diluted among the 130-odd millions in the country, often in non-malaria-supporting areas, it is evident little community risk is afforded. Multiples of this risk are offered annually by endemic malaria in the United States, and fears of exceptional virulence and resistance to treatment on the part of foreign strains have not been borne out. What risk does exist has been anticipated by the U. S. Public Health Service in extensive mosquito control projects in communities and about military installations in susceptible areas. Some returned military personnel will, of course, have recurrences of malaria, and local outbreaks may result as following previous wars, but these should remain minor and readily controllable by modern improved measures.

Historical experience indicated the general risk offered even in normal traffic by cholera, smallpox, plague, epidemic typhus, and yellow fever. Their special danger in war is a matter of record. These are the internationally quarantinable diseases, and safeguards established against them by international conventions recognize both their importance and their susceptibility to border quarantine techniques. Immunizations were employed against all of them by the Armed Forces along with water control, environmental sanitation, and disinfection and insect control by newly developed methods. These precautions were exercised even under combat conditions, as parts of preventive medicine toward combat efficiency. Results were evident. Smallpox occurring in the Army overseas was limited to 115 cases along with 64 of typhus and 13 of cholera through December, 1945. There were no cases of yellow fever or of plague.

Elaborate quarantine procedures in traffic to the United States were established by both Services, based on selective accomplishment of the above protective measures before departure from abroad. Only seven cases of smallpox have occurred to date in Army traffic to this country, and most of these arrived in patient status with full attention to contacts. It is possible but not clear that some secondary infection has occurred in Seattle and San Francisco.[1] One mild and atypical infection with typhus was recognized in himself by a medical officer on arrival in the United States after special work with the disease. Eleven typhus infections occurred among prisoners of war brought to the United States. No secondary cases developed, all prisoners having been disinfested before shipment and again inspected on arrival. It is apparent that risk of the quarantinable diseases has been negligible.[1] It may also be pointed out that several hundred cases of endemic smallpox are reported annually in the United States; twelve occurred among military personnel during the war.

Eight lepers were returned from Army personnel abroad in the past four years; all but one had a previous family history of the disease and none are considered contracted abroad, (nine others were detected before shipment overseas). Three Japanese and one Italian prisoner were leprous and were hospitalized during their entire stay. Had all these been new and unrecognized infections they would not have equalled the acknowledged risk in New York City alone.

Scrub typhus or tsutsugamushi disease has been reported in 6,800 cases. Other than one instance, no active infection has been recognized after return to the United States. This was to be expected from the short incubation period of the disease and the fact it is usually contracted in field exposure. Persons so occupied are not likely to return to this country suddenly. Nor are infected mites likely

to survive transportation in clothing or salvage in view of their fragility. Sandfly fever, of which some 12,000 cases were reported, is subject to similar limitations, and no cases have been recognized after return.

Dengue is sporadic in certain southern states and a handful of cases occurred there each year among troops. No case has been recognized among persons returning from overseas to the continent. Nevertheless, the disease did occur in Hawaii beginning in 1942, probably introduced by returnees from forward areas in the Pacific. Vigorous control was instituted in cooperation with Territorial authorities. The outbreak was well controlled, and no case has now been reported for several months.

Filariasis was much feared in some quarters early in the war, primarily as a hazard to troops themselves. All recognized cases were evacuated from endemic areas at once and slightly over 2,000 diagnoses have been made in the Army. None of these cases showed chronic elephantiasis which would be expected only from prolonged exposure and repeated infections. Microfilariae have been found in the blood with the greatest rarity. Even concentration techniques have routinely failed to show them, and risk to the general populace is obviously negligible.

Leishmaniasis has been diagnozed among hospital admissions 307 times including both cutaneous and visceral forms. No secondary cases have been reported. In view of the vigorous treatment accorded these infections and the necessity for all elements of an intermediate mechanism before transfer can occur, introduction of the disease into this country is most unlikely. The same pertains to relapsing fever, 220 cases of which have been reported almost evenly within and outside the United States. That it was predominately if not entirely tick-borne is suggested by the control of louse-infestation of troops, without which a different problem might have been presented. Self-limitation and fortunate susceptibility of the disease to therapy, and emphasis on control of lice and other insects among troops comprise the protection of our civilian population. Furthermore, relapsing fever, as mite typhus, is a disease of field conditions, and it is again improbable that persons recently exposed will often be returned within the incubation period. Once ill, they can be treated effectively before travel.

Future risk of all disease characteristically contracted under field conditions, will, of course, diminish with cessation of combat and with the advantages of essentially garrison life. This affects favorably the risk of all diseases so far considered, and of numerous others, especially the dysenteries and dermatoses.

Onchocerciasis, trypanosomiasis, Guinea-worm, and yaws have not been experienced in U. S. troops. In the last analysis the common illnesses abroad, including the tropics, are those which are common at home, and with the exception of combat injuries the same pertains to disabilities in war.

Schistosomiasis was contracted by some 1,200 men, mainly on Leyte, and for reasons already indicated additional significant numbers need not be expected hereafter, even among garrisons in infected areas. These cases have generally been mild, and because exposure was of limited duration the late cicatricial changes, which underlie the disability of indigenous cases, will probably rarely occur. For the same reason dissemination of ova should be infrequent, but principal protection of the homeland community will be afforded by its generally excellent sewage disposal. Furthermore, it has not been shown, despite intensive search, that any domestic snail is suitable for the life cycle of the oriental disease in the United States. In any event, risk from service personnel will probably not approach that associated with Shistosomiasis mansoni in imported farm labor from Puerto Rico.

Amoebiasis and bacillary dysenteries have occurred, too, but foreign strains have appeared no more virulent than those already widely disseminated in the United States. It has already become evident that chief protection against these diseases, including Ancylostomiasis, lies in well recognized and widely applied principles of waste and water care.

Approximately 20 soldiers have been diagnosed as having Japanese-B encephalitis. Considerable apprehension attached to this disease and the small number of cases to date is highly gratifying. Lack of established epidemiology is most impressive in evaluating risk to this country. Despite demonstration of mosquito vectors, the unknown rather then the known underlies our apprehension. This has been true of many diseases in history. Much comfort is gained from the proved preventive value of distance, small numbers of carriers, dilution, and continuing military alertness and medical care. Should significant outbreaks occur abroad, it is axiomatic that the full military program of preventive medicine will be applied, including probable immunization.

Much attention has been devoted by the Army and Navy to possible introduction into the United States of new species of vector insects. Disinfestation of aircraft was made a responsibility of flight personnel under supervision of the Medical Department and is routine at stations of take-off for this country. To date there is no evidence that any alien form has been implanted. It is possible this might not yet be apparent.

As previously stated, this report must be tentative. Nevertheless, favorable conclusions seem justified. Despite unprecedented breadth of travel and exposure, the military forces of this country in World War II have not subjected the United States to significant risk of disease from abroad. In many respects risk has been less than in normal prewar traffic.

This has not been the result of any single factor, but rather of the entirety of modern preventive medicine applied intensively by both Army and Navy. Exotic disease did occur and breaches of formal quarantine are acknowledged. But extensive investigation of likely hazards and critical application of preventive and corrective measures were effective in reducing risks to small proportions. This was undertaken first to preserve effectiveness of combat forces through protection of personnel in the field. Primary efforts were therefore directed to local risks and to men exposed to them. Measures included immunizations, protective clothing, insect repellents, water purification, waste disposal, mosquito and other insect control and additional environmental sanitation. The development and widespread adoption of suppressive medication and insecticides, and education of men and their officers to risks incurred were parts of this program. Quarantine precautions were established which took maximum advantage of the preventive care of the individual to assure safety to countries of entry. This was a re-orientation of quarantine procedure which is ordinarily directed at momentary observation when international borders are crossed. The military technique is fully applicable only when the responsible agency has control of the traffic throughout, but the principles involved should be of advantage in further development of international health measures.

Further protection has been afforded the United States after entry of military traffic. Thus personnel generally remain under military medical care for the duration of the important incubation periods, hospitalization has been available for the sick, and none have been returned to civilian status until maximum benefit has been offered. This has minimized risk to the patient and to his community.

A final link in protection of this country is the generally high level of sanitation, insect control, and medical care here available. Their continued assurance is a special responsibility of organized medicine. The total effect of the several factors herein discussed is a defense in depth based on broad application of preventive medicine, an essential field of medical science never so fully developed as during the recent war.

RECENT ADVANCES IN PATHOLOGY

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Research in the general and special fields of pathology during 1945 has been handicapped by World War II, with its great demand on manpower and the numerous pressing problems it put before the scientific minds of the nations at war. For this reason we find what little progress has been achieved in the fields of pathology nearly exclusively recorded in the North and South American literature. For the purpose of a better survey, the contributions which impressed the reviewer as "advances" in the fields of pathology will be discussed under the sections of: pathology of infectious diseases, intoxications, nutritional and metabolic disorders, circulatory disturbances, and diseases of unknown origin. Advances in the pathology of tumors, endocrine and nervous disorders are being reviewed by other members of the symposium in the medical science section and will be therefore omitted.

I. THE PATHOLOGY OF INFECTIOUS DISEASES

One of the most interesting contributions in this field seems to the reviewer a series of articles by Cavelti and Cavelti (1) on the pathogenesis of glomerulonephritis. They were able to produce in 127 out of 208 animals truly progressive lesions of glomerulonephritis by injecting a mixture of streptococci with homologous kidney antigen. Twenty-four animals died in the stage of acute glomerulonephritis; in 27 the glomerulonephritis went into a latent stage, and in 34 animals slowly progressive chronic glomerulonephritis was observed.

Another successful attempt to reproduce a frequently observed human infection in animals is reported by Clawson (2), who observed valvular lesions in rate after the intracardiac injection of Strep. viridens and Strep. hemolyticus. The lesions were not caused by the toxic effect of the organism, nor were they caused by an allergic reaction to the organism. Microscopically the lesions resembled closely those observed in acute rheumatic valvulitis in man.

The pathognomonic significance of the Masson body in rheumatic lesions of the lung were disputed by Herbut and Manges (3). From a study of 505 cases of unselected lung lesions over a period of 15 years, the authors concluded that Masson bodies represent intra-alveolar exudate in various stages of organization and are not specific for rheumatic fever or rheumatic pnuemonitis.

In continuation of their experiments on the relationship between swine brucellosis and human Hodgkin's disease, Brown, Forbus and Kerby (4) emphasized the similarity in the reactions produced in the lymph nodes of the hog by infection with the Brucella strain isolated from a human case of Hodgkin's disease and the strain naturally occurring in swine. On the other hand, they admitted that they have been unable to produce a disease entity comparable with human Hodgkin's disease.

In the field of fungus infections we find the interesting observation of Butt and Hoffman (5), who obtained close to 26% positive coccidioidin reactions in 700 cases admitted to the Santa Fe Coast Lines Hospital in Los Angeles. Autopsy of cases with positive skin tests revealed nodular fibrous lesions in which spherules and endospores of C. immitis were present in 45.4% of the cases with positive reactions.

The experiences of American doctors in the Pacific and African theaters of war gave rise to numerous contributions in the field of pathology in tropical diseases. As an example we may quote the study of Rifkin and Thompson (6) on the changes in early filariasis as observed in cases received from various islands in the South Pacific. The acute stage observed during the invasion of the parasite is mani-

fested by typical allergic reactions which are always local but may be also systemic. The subacute stage of infection is characterized by the development of granulation tissue in the lymphatic organs harboring the parasite. The chronic stage is characterized by nonspecific fibrous overgrowth in the areas of the degenerating parasites. The latter is then followed by lymph stasis and elephantiasis.

Also from the theater of the Pacific come our experiences with scrub typhus, or Tsutsugamushi disease. Allen and Spitz (7) compared the pathology of scrub typhus with that of other ricksettsia diseases. The focal encephalitis in scrub typhus and epidemic typhus can be well differentiated from the microinfarcts of Rocky Mountain spotted fever. Only slight vascular damage is found in scrub typhus in contrast to epidemic typhus. The authors believe that the fibrinoid degeneration of collagen, the necrotic changes in lymph nodes and spleen, and the acute diffuse glomerulonephritis are evidence of the action of allergens in ricksettsia diseases.

Numerous papers deal with the pathology of virus diseases. Pinkerton, Smiley and Anderson (8) studied the cytology of infantile giant cell pneumonia. They found cytoplasmic and nuclear inclusions which seemed identical with those seen in distemper infections of dogs and lower animals. This observation suggested to them a possible etiologic relationship between both diseases.

Lucas and Riser (9) studied the intranuclear inclusions found in the panleukopenia of cats. They found two types of granular nuclear inclusion bodies: clustered granular, and diffuse granular ones. Morphologically these inclusion bodies are identical with those found in the liver of yellow fever and severe burns, but the developmental cycle of the inclusion bodies seems a different one.

Lillie and Armstrong (10) studied the pathology of lymphocytic choriomeningitis in mice. If other routes of inoculation than the cerebral one were employed, the changes in the visceral organs were more striking. Fatty degeneration and focal necrosis of the liver, polyserositis of pleura and peritoneum, focal necrosis in thymus, spleen, lymph nodes and bone marrow were present in animals injected parenterally with the virus. From this study it appears probable that the spontaneous infections not using the intracerebral route of inoculation could produce visceral lesions more frequently, and that such lesions may well dominate the picture.

Saphir (11) reported the autopsy findings of 17 patients dying from poliomyelitis. In 10 cases diffuse lymphocytic myocarditis was present, in 6 cases interstitial pneumonia was found, in 5 bronchopneumonia. The author suggested that the myocarditis, which can only be detected by microscopic examination, may be responsible for the sudden death of some patients.

II. PATHOLOGY OF INTOXICATIONS AND TRAUMA

The interest of the pathologist in lesions encountered in various industrial occupations is evidenced by a series of articles in the field. Haythorn and Taylor (12) attempted to throw light upon the puzzling fact that in many cases patients with a considerable chemical silica content in their lungs did not show any clinical or pathological findings of the disease. Silica was extracted from silicotic lungs under careful preservation of the physical and chemical status and injected into rabbits and guinea pigs. Identical experimental lesions were obtained as with crystalline silica. These experiments proved to the authors that silica recovered from the lung has not lost any of its toxic properties by its "sojourn" through the body tissues.

In studying the effect of beryllium intoxication, Gardner and Heslington (13) produced atrophy of the spleen, progressive cirrhosis of the liver, and cortical sclerosis of the long bones, spines, and ribs. Seven rabbits surviving the injection of zinc beryllium silicate for seven months developed malignant osteosarcomas with metatases in 4 animals.

Hirsch and Russell (14) reported the case of a furniture manufacturer who died with chronic progressive induration of both lungs which had the microscopic picture of lipoid pneumonia. Extraction of the lungs with alcohol ether yielded a large amount of shellac-like material which when injected into rabbits caused necrosis and a marked exudative and fibroblastic inflammation of the lung.

The steady increase in the use of sulfa drugs and other antibodies has produced fatal lesions which have been studied by the pathologist. Black-Schaffer (15) summarized the changes found in 5 cases of fatal sulfonamide intoxications as follows: vascular lesions ranging from intramural edema to necrosis of vessel walls, and cellular exudates in skin, renal pelvis, mediastinum, gastro-intestinal tract, and other organs showing macrophages in the stage of active phagocytosis. The author believes that both types of lesions are identical with those found in experimental protein anaphylaxis.

Herbut and Scaricaciottoli (16) reported two fatal cases following sulfadiazine administration. They too emphasize the anaphylactic nature of the reaction, particularly of the diffuse hepatic necrosis.

The recent catastrophe in Boston and the use of fire as a potential weapon of war reawakened the interest in the pathology caused by excessive heat. Moritz, Henriques, and McLean (17) studied the effect of inhaled hot air on the respiratory tract. They found that the burning of the skin and mucosa of the mouth, together with fatal obstructive edema of the glottis preceded and prevented the appearance of thermal pneumonitis.

Baker (18) studied 96 cases in which cutaneous burns or complications thereof were the chief cause of death. The author emphasized the lack of specific histopathological findings and attributed most of the changes to shock, secondary infection, or in rare instances, hemoglobinemia.

III. NUTRITIONAL DISTURBANCES AND METABOLIC DISORDERS

A very interesting paper regarding the liver changes in pellagra was published by Gillman and Gillman (19). The authors performed over 600 biopsies in 120 cases of various types of nutritional deficiency. In all instances they could find evidence of liver damage ranging from minimal fatty changes to severe and progressive cirrhosis with iron pigmentation. The authors speculated upon the cause of this iron retention and came to the conclusion that it represents a sign of a disturbed mitochondrial function. They also emphasized the diagnostic importance of pigmentation with cirrhosis (pigment cirrhosis) in cases of pellagra.

The distribution of phosphatase in the liver under various metabolic conditions was studied by Wachstein (20). He found that the atrophic liver cells of starving animals and the hypertrophic liver cells of protein deficient animals showed an increase in alkaline phosphatase. Toxins disturbing the cellular metabolism, such as phosphorus and carbon tetrachloride, produced a decrease in the enzymatic activity of the injured lever cells.

Fitzgerald and Kinney (21) reported a case of rare metabolic disorder: intestinal lipodystrophy, or Whipple's disease. The case was complicated by the presence of an acute hemolytic anemia and leukocytosis. Lindsay and Knorp (22) studied a case of primary systemic amyloidosis, a condition much rarer in the United States than on the Continent.

IV. PATHOLOGY OF CIRCULATORY DISTURBANCES

The question of the importance of cholesterol in the production of arteriosclerosis was reopened by Pollak (23), who demonstrated that the lesions produced in the rabbit aorta are comparable to the lesions in the human. Ligation of both carotid arteries, both jugular veins or of one carotid artery and one jugular vein

produced lesions in the brain suggestive of hypertension. Those changes differ from the atherosclerotic lesions and can be explained by the impairment of the rate of blood flow with concomitant changes in the intravascular tension.

Interesting experiments in the field of hypertension are the successful attempts of Dick (24) to produce high blood pressure in dogs by injecting intravenous doses of live streptococci from various sources. The kidneys showed the picture of benign nephrosclerosis with scarring of the surface, fibrosis of glomeruli, and atrophy of tubules.

Flory (25) found 9 cases among 267 autopsies of persons with advanced atherosclerosis of the aorta showing evidence of embolic occlusions of smaller vessels in various visceral organs (spleen, pancreas, and kidney). He could produce the same type of lesion by injecting material scraped from atheromatous ulcerations of human aortas in the pulmonary vessels of rabbits.

Holyoke (26) studied 70 hearts with the injection technic of Schlesinger. In 12 instances occlusion of branches of the coronary vessels could be found at several points. In all hearts showing narrowing of the coronary branches interarterial anastomoses could be demonstrated. The author believes that the prompt establishment of such anatomosis could minimize greatly the danger of myocardial infarction in case of coronary occlusion. It is his opinion that other factors than simple coronary occlusion must play a part in the production of myocardial scars.

The importance of proper peripheral circulation was stressed in a study on the pathology of trench foot by Friedman (27). He concluded that all injuries resulting from exposure to low temperature followed the same train of events. A disturbance in the circulatory mechanism leads to stagnation of blood in the smaller vessels with thrombosis and gangrene, which then becomes complicated by secondary infection. Permanent changes produced in these vessels by the first exposure is the cause for the delayed sensitivity to cold temperature.

V. DISEASES OF UNKNOWN ETIOLOGY

In the field of diseases of unknown origin we may quote two studies which although they failed to prove the etiology advanced our knowledge of the diseases.

Bevans (28) studied intensively two cases of generalized scleroderma. In addition to the typical skin lesion she found myocardial fibrosis, perivascular and peribronchial fibrosis of the lung, and extensive vascular lesions in the medium sized and smaller arteries of the kidney. There were also present an atrophy of the smooth muscle of the esophagus and patchy atrophy of the smooth muscle tissue throughout the intestinal tract. The author emphasized the vascular lesions and degenerative changes of smooth muscle tissue as important factors in the pathogenesis of the disease.

Bayley, Lindberg and Baggenstoss (29) reported the first case of Loeffler's syndrome which came to autopsy. The syndrome, described in 1932, is characterized by a transitory pulmonary lesion which is usually interpreted as pneumonia, peripheral eosinophilia, and a good prognosis. A 59 year old woman complained of severe cough, restlessness and anorexia. Her blood count showed 35% eosinophils, and the x-ray picture showed dense shadows in both upper lobes. The patient improved but recurrence of her symptoms brought her back three months later. Death occurred five days after her second admission. The histological examination of the lungs showed nodular areas of fibrosis, eosinophilis, plasma cells, lymphocytes and some giant cells. Necrosis of medium sized and small arteries and veins was found with an exudate consisting largely of eosinophils and plasma cells. No evidence of a microorganism could be found bacteriologically or histologically.

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RECENT ADVANCES IN OBSTETRICS AND GYNECOLOGY

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It has been said and repeated over and over again that "there is nothing new under the sun," and so it seems to be, with what appear to be the recent discoveries and advances in this particular field. There have been some re-discoveries of old principles and re-application of these principles to modern obstetrics and gynecological surgery. There has been the application of relatively new things in the field of general medicine and surgery to this particular specialized field. There has been, too, the popularization of methods which have been preached and advanced by men of other years, yes, even of other generations, so that they are in common use today, whereas, five years ago they were considered either obsolete or the use of them, by a few scattered individuals, as the first signs of senility or psychosis. Indeed, there are not only a few if any new discoveries in this field, but in some instances a few steps "backwards" may be interpreted as a distinct advance. And I refer particularly to the discontinuance of the promiscuous use of the heterogenous gonadotropic hormone preparations clinically for their supposed beneficial effect upon the human ovary, as regards the stimulation of an abnormally functioning or a hypofunctioning ovary, as far as ovulation or the restoration of normal cyclic metabolism is concerned (1). A very few years ago these substances, particularly the equine gonadotropins and their use was reported with great enthusiasm as a distinct advance in the field of gynecological endocrinology. The use of these substances may cause far greater harm than any temporary good. They are still promoted by some commercial institutions and are still used by some inexperienced clinicians, but their large scale use has, in all medical centers, long since been dropped.

However, there has been some advance in the management of functional irregularities of uterine bleeding. It has been conclusively shown that the use of Vitamin B complex used without any specific endocrine therapy will bring about a cure in a large percentage of instances. It is interesting to note that some years ago, before the advent of specific endocrines for the management of this type of case, the treatment of the anemia, which was associated with profuse menstrual bleeding, had a beneficial effect, and this was particularly true in those cases in which the anemia was treated with crude liver extract. As the liver extract was purified more and more it was found that the beneficial effect diminished, in fact, it was almost negligible insofar as the menstrual function was concerned. It was also found that a fat soluble by-product of the purification of liver extract seemed to contain a factor which also had a beneficial effect upon menstrual dysfunction, and especially upon a profuse menstruation. It was felt that this was the substance responsible for the change brought about by the use of crude liver extract. However, it is our experience that Vitamin B complex produces much better effect than this so-called antimenorrhagic factor derived from the liver. It might then not be too far fetched to suppose that part of the beneficial effect attributed to the liver extract could have been due to an increased intake of the Vitamin B complex. Vitamin B complex in this particular aspect has been used alone or can be used only as an adjunct to the standard attack, that is the use of thyroid substance, attention to diet, exercise, and the like.

In the field of cancer control generally, and especially in the detection of early cancer in the so-called inaccessible organs and with particular reference to the educational campaign there has been a very great step forward in the early detection of cancer of the cervix. This has been championed by Dr. MacFarlane and others in Philadelphia (2) and more recently by a Chicago group (3). Their work

is worthy of report here. They undertook to determine the value of periodic pelvic examinations for the detection of cancer of the cervix in an early and curable stage and in the detection of imflammatory lesions of the cervix which may predispose to cancer. By means of appeal to patients, women's clubs, nurses' auxiliaries, social service agencies and the public at large through the press, 1,319 volunteers were found. All were presumed to be well. They volunteered to come for examination twice a year for five years as a contribution to medical science. The examination, intentionally, was kept so simple that it could be duplicated by any physician and consisted of a careful bimanual examination and a careful inspection of the cervix in a good light. Up to May 15, 1944, 9,111 pelvic examinations had been made. In the first examination of these volunteers, early cancer of the cervix was discovered three times. The fact that these three cancers of the cervix were discovered in areas of papillary erosion and not in healthy noninflammatory cervices was significant and lends great support to the theory that cancer can develop in these so-called areas of epithelial unrest. At the Chicago Clinic, of the first 600 patients examined, ten were found to have cancer of the cervix. Erosions of the cervix were found in 75 cases, with treatment advised, and two cancers were found elsewhere in the female generative tract. The calling attention of these facts to the medical profession and to the public at large may result in the distinct advance of cancer control in regard to the female genitalia, but the real advance will only be made when the laity and the profession are taught that early uterine cancer is cureable; that time is important; that hormones do not cure all gynecological disorders; that menstrual irregularities during the menopause are not normal; that irregular vaginal bleeding at any age may indicate early carcinomatous changes, or that unexplained vaginal bleeding, especially postmenstrual bleeding, can be caused by cancer and does not always result from endocrine deficiency, fibroids and the like, although they may be associated with them, and that vaginal discharge in adults may be an early sign of a malignant condition. In regard to the treatment of cancer of the cervix, it is a well known fact that it has always been generally unsatisfactory, even in early tumors. The original Wertheim operation for carcinoma of the cervix as practiced, perhaps before the advent of what we may consider now newer surgical technique and post-operative care, carried with it too high a mortality rate. Its favor gave way to radiation therapy entirely in many clinics and in fact the surgical treatment of cancer of the cervix has been until recently frowned upon by many. As the actual matter of fact, the result of the radiation treatment of cancer of the cervix has actually been no more satisfactory, except that the initial operative mortality was extremely low, but in those individuals who are not cured, the mortality rate from the cancer was still 100 per cent. There has been a constant search, of course, for the ideal method of treatment. Taussig brought forward, several years ago, the combination of irradiation with radical dissection of the lymphatics draining the cervix. By this combination therapy, he felt that his results were better. More recently there has been restated the argument for surgical treatment of cancer of the cervix, especially by Dr. Meigs of Boston (4). He has combined the original Wertheim radical excision of the internal female genital organs with the pelvic operation for excision of the lymphatics. Meigs has reported an astounding survival rate of 96.3 per cent in cases in which there was no lymph node involvement by this operation and a corrected survival rate of 87.7 per cent of all cases. These are undoubtedly by far the best results obtained by radical operation for cancer of the cervix.

Recently reported (5) has been the extremely high incident of all types of congenital anomalies, probably most frequently occular and cardiac defects in babies born of mothers who has contracted rubella or German measles during the early months of their pregnancy. It is generally conceded that 100 per cent of mothers who contracted rubella the first two months of pregnancy will give

birth to infants with some form of congenital anomoly, and about 50 per cent of mothers who contract rubella in the third month have abnormal babies. It is considered by some a very definite indication of therapeutic abortion if the mother has contracted rubella during the first two months of pregnancy. Also very definitely indicated, is the avoidance of contact of women in early pregnancy with known cases of German measles. The use of immune globulin for the protection of women in early pregnancy, who have been exposed to rubella, has been advocated.

Early postoperative ambulation, as we use it today and as it is being practiced more and more, is most certainly a distinct advance in the care of surgical patients and especially in respect to abdominal surgery. The reduction of postoperative complications and a much earlier feeling of well-being by the patient are distinct advantages. The incidence of postoperative thrombophlebitis, which is especially prone to follow all types of pelvic surgery, and the incidence of pulmonary embolus, has been greatly reduced by ambulation. Abdominal distention, ileus and troublesome gas pains are also greatly reduced by early ambulation. Pulmonary complications, such as atelectasis, pneumonia, etc., are rarely seen where early ambulation is practiced. Not too long ago patients were kept in bed as long as twenty-one days following a hysterectomy. It is now practiced here and in many clinics to get the patient out of bed, or at least up on the edge of the bed, on the day of operation and to gradually increase their time up daily thereafter so that most of these individuals are ready to leave the hospital within seven to ten days.

The newer forms of chemotherapy, sulfonamides and penicillin and its related compounds have reduced the mortality rate and the long time morbidity rate of the one time dreaded child-bed fever to almost nothing. The same may be said in regards to the reduction of the incidence of breast abscess in the puerperium. In addition to this, treatment of the acute pelvic inflammatory disease in the post-abortion state and that which is primarily due to gonorrhea, with these drugs, has reduced remarkably the number of patients coming to surgery because of the sequalae of these infections. The resolution which is seen in some of these individuals with acute inflammatory disease of the pelvis is almost unbelievable, when they have been treated with these drugs, and especially the combination of the sulfonamides and penicillin.

Continuous caudal anesthesia has become quite popular in many clinics in the past five years and has been rather widely used. This is shown by the fact that over 100,000 deliveries with this method have already been recorded in the literature (6). This method is not, however, without danger and disadvantage. It is a highly specialized form of anesthesia and entails among its dangers, death. Briefly, it is a method devised to maintain continuously access to the caudal canal through which an anesthetic agent can be administered intermittently during labor and over a relatively long period of time. The chief advantage of continuous caudal anesthesia are the absence of depression in the baby, low toxicity to the mother and the complete absence of pain during the uterine contractions and delivery.

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RECENT ADVANCES IN CARDIOVASCULAR DISEASES

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In the field of congenital heart malformations, several recent advances in treatment have altered our approach to what was once considered a hopeless problem. Some years ago Gross first introduced surgical intervention in the treatment of a patent ductus arteriosus. This communication between the aorta and pulmonary arteries normally closes shortly after birth. The persistence of a patent duct seriously alters normal adult cardiovascular dynamics. Although some patients live a comfortable life, most of them develop subacute bacterial endocarditis or progressive congestive heart failure. Gross (1) conceived and perfected the surgical technique of ligating the patent ductus with a minimum of operative risk. Although the procedure is not always technically possible, the results in a great majority of patients are highly gratifying. The indications for surgery are subacute bacterial endocarditis or beginning cardiac embarrassment.

Within the past two years Blalock and Taussig (2) conceived the idea that perhaps an arterial shunt could be created to circumvent a congenital stenosis of the pulmonary artery or valve. The children suffering from this lesion are pitiable creatures, with their intense cyanosis, severe dyspnea and clubbed fingers. The technique, after careful experimental studies, was finally carried out in children with an otherwise hopeless prognosis. It consisted of anastomosis of a large arterial branch of the aorta to the pulmonary artery or one of its main branches beyond the point of stenosis. Preliminary reports are very encouraging.

Gross and Hufnegel (3) have reported resection of the area of atresia for correction of coarctation of the aorta. This procedure involves much more difficult surgery and there is no series of cases to present as a basis for discussion. But the ice has definitely been broken and much more accurate differential diagnosis of congenital heart lesions is desirable in order to uncover those that might now or in the future be amenable to surgery.

There have been several recent advances in the field of acute rheumatic fever and rheumatic heart disease. Most reports indicate a favorable response in the prevention of acute rheumatic fever by small daily doses of Sulfadiazine. An average of 0.5 to 1.0 grams daily is considered as adequate dose. Toxic reactions are few but the blood count should be followed at frequent intervals. There is some question concerning the development of sulfa-resistant strains of streptococci; this problem has not been settled. However, we do know that sulfa drugs are contraindicated during or within three months after an attack of acute rheumatic fever. The possibility of applying the same principle to the use of oral penicillin offers hope in the future of perhaps several agents to reduce the acute recurrence of this disease.

Coburn (4) has re-opened the question of the therapeutic value of salicylates in the treatment of the acute stage of rheumatic fever. He has recently treated a series of cases with massive doses of salicylates and is convinced that cardiac involvement is lessened and the duration of the acute stage shortened. This also re-opens the question of the fundamental effect of salicylates on antigen-antibody reactions in the body and, hence, on the prophylactic as well as therapeutic effect of salicylates on the hypersensitive rheumatic fever patient. There is not general agreement on this subject but the prospect of a more favorable course of the acute disease appears to be worthy of close scrutiny.

The past two years have seen the only real advance in the treatment of subacute bacterial endocarditis. Before the use of penicillin, I had never seen even one patient recover from this disease but in the past two years have indicated

recovery in 25 to 75 per cent (5). The dosage of penicillin necessary, the methods of administration and the length of treatment have been pretty well worked out. Three hundred thousand to one million units daily by continuous intravenous or intrasternal route for a period of six weeks seems at this time to be the most satisfactory regimen. The most important points to be remembered are: 1, the earlier the diagnosis is made the better the prognosis; 2, the daily dose should be optimum rather than minimum; 3, treatment should be continued for several weeks after negative blood cultures have been obtained, and 4, anticoagulants are of no value in the therapy and are in fact definitely contraindicated.

The prevention of subacute bacterial endocarditis following nasal and oral surgery and extraction of teeth in known rheumatics is an equally great stride in therapeutics. Perhaps it would be proper to say that it is more important than treatment of the disease. Sulfadiazine 1 gm. every four hours for twenty-four hours before and forty-eight hours after such procedures is the present method of choice. It should be routine practice to stress to all our known rheumatics the dangers involved and the importance of proper prophylaxis even though the extraction of a tooth may seem a trivial procedure. Perhaps in the future oral penicillin will supplant sulfa drugs.

In spite of intense study of the causes and treatment of hypertension by many investigators, there is little for me to report. The status of medical treatment has changed but little. Surgical treatment by sympathectomy has been the subject of much controversy; some patients so operated have seemed to respond nicely whereas others presenting a nearly similar clinical picture have not. In the past the cold pressor test, the pentothal anaesthesia test and spinal anaesthesia test have been used singly or in combination in an attempt to select for surgery those cases which might, on the basis of the results of the tests, be expected to show optimum improvement. Postoperative results have not been uniform. Russek, Southworth and Zohman (6) recently reported a new procedure for the prediction of a favorable or unfavorable response to sympathectomy. Their method employs the use of continuous caudal anaesthesia which may be maintained at any segmented level. The results of blood pressure determinations during anaesthesia are reported as a reliable index of the response to surgery in approximately 90 per cent of cases.

Wright (7) reported recently of a neurovascular syndrome due to hyperabduction of the upper extremity. He found changes in the pulse in approximately 84 per cent of normal young males when the upper extremity was placed in this position. Some of these complained of numbness, tingling and pain when the arm was maintained in this position for even short periods of time. Wright felt that most persons would return the arms to normal position even during sleep but he reported several cases which had severe day-long disability due to continued maintenance of hyperabduction during sleep. One of his cases had tropic changes in the finger tipe because of prolonged interference with circulation. The etiology is distinct from the scalenus anticus syndrome and results from the pinching of the subclavian artery and brachial plexus between the first rib, pectoralis muscle and clavicle when the upper arm is hyperabducted.

In the treatment of congestive heart failure, I feel there has been a recent very outstanding advance, one which will help to clear up some of the confusion about variation of potency of various digitalis preparations. Crystalline Digitoxin is available in tablet and ampule form under various trade names. In contrast to oral digitalis leaf this preparation is completely absorbed in the G-I tract and 100 per cent of the drug administered is utilized; it causes very few undesirable symptoms such as malaise, anorexia, nausea and vomiting. Massive single-dose oral or intravenous digitalization can be easily accomplished as a routine measure with great safety. The dose is 1.2 mgm. to 1.6 mgm. or six to eight tablets; maintenance dose is 0.1 mgm. or 0.2 mgm. or one-half to one tablet. In my experience it is tolerated by elderly patients much better than digitalis leaf.

It is probably the best product for routine use because of ease of dose calculation, ease of administration and better tolerance.

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PHYSIOLOGY

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In this paper an attempt will be made to describe some of the recent advances in the physiology of both the nervous system and the endocrine glands. While the peculiar interests of the author dictated the selection of material, it is hoped the subjects chosen are of general interest.

The pituitary-adrenal control of the release of antibodies from lymphoid tissue.

One of the more interesting recent contributions to physiology has been the demonstration of a functional relationship between two of the endocrines and the activity of lymphoid tissue. Since the present concepts are based on seemingly unrelated investigations in fields far-removed from each other, it is considered desirable to briefly review the more important points upon which these ideas are based.

As a result of careful correlation of the isolated data of previous workers and crucial experiments of his own, Selye, 1936, introduced the concept of an "alarm reaction," a typical series of events taking place whenever the organism is subjected to severe stresses or damaging agents. (1) As a part of this reaction the lymphoid tissues, lymph nodes, thymus and spleen undergo involution, while the adrenal cortex hypertrophies. It was also established by Selye (2) that the lymphoid tissue changes in the alarm reaction do not take place if either the pituitary or adrenals are absent. The nature of this dependence of the lymphoid tissue on the adrenal and pituitary was shown by Dougherty and White (3) who found that anterior pituitary corticotrophic factor caused atrophy of the lymphoid tissues when injected into intact animals, but not when administered to adrenalectomized animals. They further found that administration of adrenal cortical extract or corticosterone causes involution of lymphoid tissue. These facts taken together with the histochemical finding of a greater secretory activity of the adrenal (3, 6) during the alarm reaction, show that the lymphoid tissue involution comes about because of an increased output of adrenal hormone, the release of which is under the control of the pituitary.

The story does not end at this point, for it has also been observed that a lymphopenia accompanied by an increase in the concentration of the plasma proteins occurs during the alarm reaction (3, 4, 5). The lymphopenia is accounted for by the failure of the involuting lymphoid tissue to deliver ample lymphocytes to the blood stream because of liquefaction and dissolution of stored lymphocytes, while the increased plasma protein is considered to come from the destroyed lymphocytes. Electrophoretic studies have shown that this extra plasma protein consists largely of anti-body containing gamma globulin (6). Confirmation of the importance of the lymphocytes as producers of antibodies has come from the work of Harris et al. (7) and Rich, Lewis and Wintrobe (8) who employed immunological techniques. When these latter findings are taken into account it may be finally said that the pituitary acting through its influence on the adrenal controls the release of antibody globulin from the lymphoid tissues.

Relationships between hormones and enzymes.

An approach to the problem of the mechanisms by which hormones really exert their effects has been made through the study of hormone-enzyme relationships. The logic for undertaking such studies is clear when one considers the fact that hormones alter the metabolism of tissues and that enzymes are ultimately responsible for the energy transfers involved. Since changes in the concentrations of enzymes might well account for the changes in metabolism, the concentrations of various enzymes have been studied in different endocrine states. A number of such relationships have already been demonstrated, e.g., the concentration of cytochrome-c decreases after adrenalectomy and can be restored by the administration of adrenal cortical extract (9), liver alkaline phosphatase concentration is increased in dogs with alloxan diabetes (10) and estrogen injections lower the serum acid phosphates in intact animals (11). Since only a few enzymes in but a small number of endocrine states have been investigated, one expects to see much activity in this field in the future.

One should not leave a consideration of the hormone-enzyme relationships without mentioning the vitamins, several of which (nicotinic acid, thiamine, riboflavin and possibly ascorbic acid) go into the make-up of enzymes and co-enzymes (12, 13, 14). Furthermore, it is known that deficiencies in these vitamins result in lowered concentrations of certain enzymes and co-enzymes and thus decreases in the metabolic activities dependent upon them (12, 13, 14). In view of the fact that the levels of both hormone and vitamin exert an influence on the concentration of enzymes, it is apparent that much future investigation should be carried out to determine the details of the relationships between these three substances.

Adrenal ischemia and hypertension.

It has recently been found that unilateral subtotal ligation of periadrenal blood vessels and tissues results in the development of an hypertension, which is apparent after one to three days and which lasts for months (15). In view of the important facts emerging from the study of the ischemic kidney, one expects thorough exploitation of this ischemic adrenal preparation.

Acetylcholine and conduction of the nerve impulse.

During the past few years a theory relating acetylcholine to the conduction of impulses along nerve fibers has arisen. The facts upon which the theory is based are: (a) Nerve fibers contain and can synthesize acetylcholine (16), (b) nerve fibers contain cholinesterase (17), (c) acetylcholine possesses the ability to depolarize membranes (18, 19, 20). The theory states that the stimulus to the nerve fiber results in the release of acetylcholine which depolarizes the neural membrane rendering it permeable to all ions; this results in the generation of an

action potential which stimulates the adjacent region of the neuron and brings about the release of acetylcholine there, thus repeating the whole process. The cholinesterase present destroys the acetylcholine allowing the membrane to recover its polarization.

The authors of recent experiments (21, 22) suggest a drastic modification of this theory. They state that the action potential is due solely to acetylcholine and that the old Bernstein theory of the polarization of the neural membrane by inorganic ions is untenable.

Synthesis of acetylcholine.

Much recent work has been done to show that the synthesis of acetylcholine by brain and nerve depends upon the presence of both adenosinetriphosphate and an enzyme, cholineacetylase (23).

The autonomic nervous system.

Brief mention should be made of a new concept of the functions of the sympathetic and parasympathetic systems in dually innervated organs. The old ideas of the dual innervation by the sympathetic and parasympathetic systems and the functional antagonisms of these two systems appear to be false. In dually innervated structures such as the iris, the gastro-intestinal tract and the urinary bladder, it has been shown that the sympathetic system exerts its influence solely on the blood vessels and the parasympathetic through actual innervation of the smooth muscle of the organs (24, 25, 26).

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RECENT ADVANCES IN OTO-LARYNGOLOGY

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The most striking advances in Oto-Laryngology in the past year have been in the use and administration of Penicillin and the application of radium to the naso-pharynx.

Aerotitis is due to the inability to ventilate the middle ear. Otalgia is the first symptom, and may be so severe as to cause unconsciousness, shock, nausea, vomiting and vertigo. Labyrinthrine damage seems inevitable with such a violent accident. After pain subsides, there remains a loss of hearing with stuffiness or pressure deep in the canal (1).

Appearance of the drum parallels the symptoms. The membrane tympani is usually hemorrhagic and retracted. Hemorrhage may be in the drum or in the middle ear. The hemorrhage changes color with time, becoming a deep red and later a dark blue, while the ossicles stand out white against this background. It takes about three weeks to recover.

Hearing loss is a prominent symptom. There is no characteristic curve but the type of deafness is conductive with a negative Rinnee and Weber is lateralized to the involved ear.

Serous otitis may follow, fluid accumulates under negative pressure and it may shift with the change of position of the head. This changes the hearing as it leaves the vital structures.

The hyperplastic lymphoid tissue in the naso-pharynx is the most common cause of eustachian tube malfunction. Lymphoid tissue regresses after radium therapy about the eustachian tube. It removes not only the mechanical factor which predisposes to aerotitis, but also tissue that harbors pathogenic organisms that precipitate attacks of naso-pharyngitis. This lymphoid tissue about the eustachian tube is the most common cause of conductive deafness in children and predisposes to repeated attacks of otitis media. Of 6,881 (2) men, 74% were benefited and 89% showed a marked decrease in adnoid tissue, definite improvement in hearing, and in the ability to ventilate the middle ear.

Dr. Lempert (3) offers a new theory and suggests that tinnitus aurium in many cases and under certain conditions may be due to a tonus impulse transmitted to the inner ear by disease of the sympathetic ganglion cells of the tympanic plexus. Based on this new theory, Tympano-Sympathectomy is recommended for the relief of tinnitus aurium.

A surgical technic by which Tympano-Sympathectomy may be performed without disturbing the hearing has been successfully employed.

Not all cases of tinnitus are embraced by this theory, and there is no definite way as yet to select the cases which apply. Nevertheless, of fifteen patients on which Tympany-Sympathectomy was performed, ten are now completely free from tinnitus. Patients selected had severe, persistent tinnitus for one year duration or more, and were unable to concentrate because of its intensity.

Dr. Lempert (4) reports over 1,000 patients with clinical otosclerosis that have been treated by fenestration of the labyrinth in the last seven years. In the last 700, the fenestra nov-ovalis was created in the surgical dome of the vestibule. Practical, serviceable hearing for all social and economical purposes was restored and continuously maintained in about 50% of the cases.

Closure of the newly created fenestra by new bone formation, and damage to the organ of Corti as a result of serous labyrinthitis, were found to be the two major obstacles. Bone formation may be stopped by cartilage stopple.

Day (5) reports approximately 80% of patients get serviceable hearing if one selects patients under forty-five years of age and with bone conduction of not less than 15 decibels in speech range. He does not use cartilage stopple.

Shambaugh (6) has an average of 25.7 decibels improvement in 321 cases operated, using the nov-ovalis technic of Lempert modified by constant irrigation of the field and the use of the binocular dissecting microscope while the fenestra is being made.

If a mastoid is operated, closed and a ureteral catheter placed in the mastoid, then irrigated with 10,000 units of Penicillin of 2 c.c. volume every eight hours for four days, it will be completely cured as reported in eighteen of the twenty-three patients tried (7).

External otitis is often a difficult disease to treat. This is due to fungus infection, humidity, temperature and secondary infection by different organisms. Thymol 1% in Cresatin will control 80% of the fungus cases, and the cellulitis of the canal will respond to Chemotherapy if gram positive organisms are present. Some of the foulest ears are sulfa resistant and are infected with *B. pyocyaneus*, which will respond in 48 hours upon packing with 5% Sodium Thiosulfate (8), followed by a 2% Acetic Acid pack for five minutes. This must be continued for several days to prevent recurrence even though the canal looks normal.

Penicillin solution of 250 units per c.c. has no effect on the ciliary beat, which normally lasts from 25–28 hours. Using 500 units per c.c., the ciliary beat was reduced to 15–19 hours; 5,000 units per c.c., the beat was reduced to 3–6 hours. Therefore, a weak solution of Penicillin has no damaging effect on the cilia or epithelium of respiratory mucosa (9).

Two c.c. of Penicillin (10–20,000 units) with 1 c.c. of 1% Novacaine injected (10) into an early peri-tonsillar swelling will give marked relief from pain in 2–3 minutes and the patient can swallow without discomfort.

Penicillin 1–300,000 units, single dose per day, in peanut oil and .02 gm. Novacaine has proven very satisfactory as an office procedure to oombat infections caused by Penicillin sensitive organisms. This leaves the patient ambulatory, quick recovery and no side reactions except delayed sore arm in some patients. Otitis media, serous otitis, acute sinusitis, septic throat and vincents, all respond faster than those cases in which sulfa was used.

J. R. Richman (11) reported a new treatment for esophageal obstruction due to meat impaction. There were 17 cases treated by oral ingestion of a proteolytic enzyme, papain powder. Twelve were relieved in an hour and a half, some of these within thirty minutes. The papain digests thirty-five times its weight of meat. I have used this four times in the last three months in patients who were very poor risks for esophagoscopy, and all were completely relieved of the obstruction within half an hour.

In bilateral adductor paralysis following injury to both recurrent nerves, the King or Kelly operations to abduct the cords have been indicated. Murtagh (12) shows us that by cutting the external branch of the superior laryngeal nerve, which supplies the crico-thyroid muscle, the cords shift permanently to a position of abduction.

Inoperable carcinoma of the larynx may respond to X-ray therapy by Coutard method, using 4–6000 Units, after complete removal of the thyroid cartilages. Arbuckle reported 18 cases recently. I have 2 cases with complete regression of the neoplastic tissue, but only two years after treatment. This offers new hope for the advanced cases of carcinoma of the larynx.

A large proportion of patients seen in the office practice of otolaryngology suffer from chronic nasal allergy, frequently complicated by a superimposed infection. The best therapeutic results can be obtained when treated simultaneously. History, stained nasal smears, skin tests, elimination diets, and therapeutic tests,

aid in the diagnosis of nasal allergy. Sensitivity to house dust is more frequently encountered than generally recognized and the therapeutic response to it, is very satisfactory in a great majority of cases.

Aerosinusitis is an acute or chronic inflammation of one or more nasal accessory sinuses, produced by barometric pressure difference between air inside the sinus and that of the surrounding atmosphere, and it must be differentiated from purulent and catarrhal sinusitis. History of a recent flight is often a deciding factor but X-ray, disclosing opacity or thickened membrane in absence of previous sinusitis, sudden pain over the sinus, epistaxis, during or after exposure to baratrauma, and no previous rhinitis, is extremely suggestive. Aerosinusitis usually responds to vaso-constriction, but polyps or other obstruction must be eliminated, and at times Caldwell-Luc is necessary.

In the management of chronic sinus diseases, simple measures, if properly applied, suffice in 97% of the cases. Attention is concentrated on the drainage area of involved sinuses and all efforts are directed toward restoration of function of the ostea. In most cases of few months duration, the opening itself is not at fault, but rather, the trouble lies in relation of adjacent tissue to the opening. The defects may be anatomic or pathologic. Most common is a blocked middle meatus by an impinging middle turbinate wedged against the lateral wall, septal deviation, spurs, cellular turbinate, etc. In pathological groups, edema from allergy is most prominent in which case the mucus membrane may swell 50 times its normal thickness in a few hours and easily block the ostium. Swelling may be a Vasomotor reaction to an endocrine imbalance, G.I. disturbance, or some other systemic condition.

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BOOK NOTICES

A New Text Book of Genetics

There is a very complete presentation of modern genetics, written by one who had the good fortune to be a member of the Drosophila group at Columbia University during the formative years of the science. Although Drosophila is used to a large extent throughout the book, many examples from human inheritance are interspersed, as well as instances from domestic and laboratory animals, and plants. The style is clear and simple, and the book is written with the viewpoint of the student continually in mind. Excellent drawings and diagrams clarify all difficult points.

The Drosophila system of gene nomenclature is used, a fact which in the opinion of this reviewer offers the greatest drawback to the usefulness of the text. Fortunately all geneticists do not share this writer's aversion to the + as a gene symbol. Excellent summaries follow the texts of the chapters, and well thought out problems are appended to each chapter. No references are given. A few typographical errors appear, but the book is remarkably free from them. Particularly good discussions are presented of chromosomal aberrations, mutations, and the bearing of genetics on development and evolution. The book is as complete and modern as a text could well be.—*L. H. Snyder.*

Genetics, by Edgar Altenburg. xii+452 pp. New York, Henry Holt and Co., 1945.

Check List of Cicadellidae

The first attempt at bringing together the species of the family Cicadellidae since the publication of the catalogue by Van Duzee in 1917 appeared in mimeograph form in 1937 under the authorship of DeLong and Caldwell. Since then generic revisions based on structural characters have resulted in many new species and some new synonomy. All these changes and additions have been incorporated into this new recently published Check List.

It lists 175 genera and 2276 species, varieties, and subspecies occurring north of Mexico Synonomy as given in the Van Duzee catalogue is not repeated. Original literature on each species is cited by number from a list near the end of the paper which saves repetition of wording names of journals or other places of publication. The specific names under each genus are alphabetized which simplifies the locating of a particular species.

A suggested list of generic papers on the family and an index to genera completes the publication.

This is an invaluable tool for those interested in classification of insects and especially those who are actively engaged in studies on the taxonomy of leafhoppers.—*Ralph H. Davidson.*

Check List of the Cicadellidae (Homoptera) of America, North of Mexico, by Dwight M. DeLong and Dorothy J. Knull. 102 pages. 1945. Ohio State University Graduate School Studies. Biological Science Series No. 1. Paper bound. $1.50.

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THE GEOLOGIC INTERPRETATION OF SCENIC FEATURES IN OHIO[1]

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INTRODUCTION

To the geologist there are no everlasting hills. The relief features of the earth's surface as we find them today are the result of the work of geologic agents, such as running water, wind, glacial ice; working by geologic processes such as weathering, erosion, transportation, deposition; on geologic materials, the rocks; through long intervals of geologic time. An even sky-line in a rugged region, a level bench on the side of a valley, an asymmetrical ridge and similar features, all have meaning and invite interpretation.

Everyone may experience pleasure in seeing the beautiful colors, the symmetrical forms, or even the fantastic shapes in scenic features but if one may also interpret and decipher the origin and history of these features, how much greater the pleasure and satisfaction derived, and the increased appreciation of the scenic features.

The Grand Canyon of the Colorado as a scenic feature is beautiful in color of rock material and impressive in magnitude, but the Grand Canyon as the work of the river which occupies it; downcutting and dissecting during 10 to 20 million years; exposing in this downcutting, rock units which differ in lithology, in structure, age and origin; rock units which by enclosed marine fossils record periods of sea incursion; rock units which by other characteristics record deposition in arid land conditions; periods of mountain building when rock strata were tilted, faulted, metamorphosed and intruded with igneous lavas; periods of long continued erosion when great thicknesses of rock strata were worn away and large areas reduced to level peneplains; when one sees all this in the rocks of the Grand Canyon, involving a duration of perhaps a billion and a half years, how much more impressive, how much more awe-inspiring the Grand Canyon becomes.

[1]Address of the retiring President of the Ohio Academy of Science, delivered at the annual meeting of the Academy held in Columbus, May 3, 1946. The publication of the illustrations accompanying this paper is made possible by a grant from the John A. Bownocker Endowment of the Department of Geology, The Ohio State University.

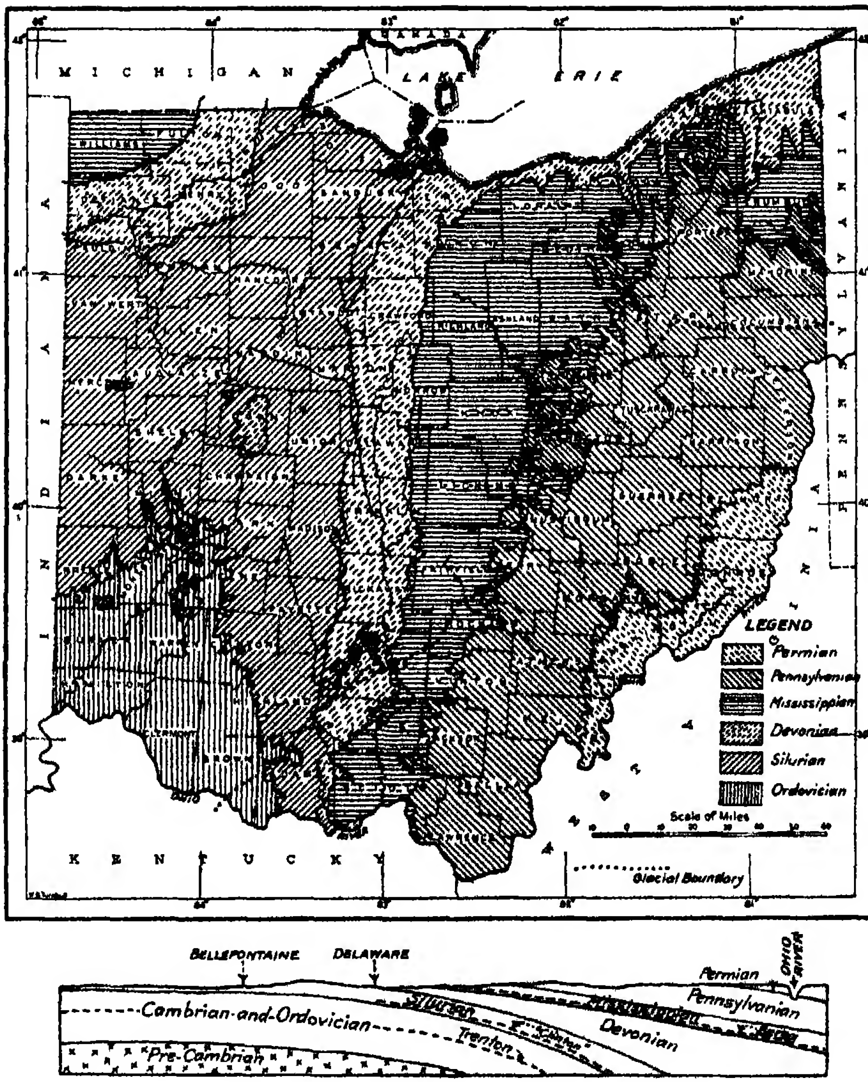


Fig. 1. Geologic map of Ohio showing the areal distribution of the several systems. Below is a west-east cross section through central Ohio. (Geol. Surv. Ohio).

SOME BASIC FACTS AND PRINCIPLES

The larger units of the standard time scale are shown in Table I, those units present in Ohio being in *italics*. All the bedrock units exposed in Ohio are of Paleozoic age, the third or middle one of the five great eras are of geologic time. The exposed rock strata range from Ordovician, the second period of the Paleozoic, to Permian, the last period of the Paleozoic.

TABLE I

GEOLOGIC TIME SCALE

Era	*Period*	*Estimated Duration in Years*
CENOZOIC	*RECENT*	25,000
	PLEISTOCENE (Glacial)	1,000,000
	TERTIARY	60,000,000
MESOZOIC	CRETACEOUS	65,000,000
	JURASSIC	35,000,000
	TRIASSIC	35,000,000
PALEOZOIC	*PERMIAN*	25,000,000
	PENNSYLVANIAN	45,000,000
	MISSISSIPPIAN	40,000,000
	DEVONIAN	50,000,000
	SILURIAN	40,000,000
	ORDOVICIAN	85,000,000
	CAMBRIAN	70,000,000
PROTEROZOIC		650,000,000
ARCHEOZOIC		650,000,000

The distribution of the several rock systems as they appear at the surface in Ohio is shown on Figure 1. The rudely belted arrangement of outcrops is due to a long north-south upward fold or anticline, with the axis extending through western Ohio from just east of Cincinnati to the western part of Lake Erie. This fold, called the Cincinnati anticline, is the dominant structural feature in the geology of Ohio. It is a very broad fold with very gentle dips to the east and west, commonly about 40 feet drop per mile. The general features of this anticline are shown by the cross section sketch at the base.

The older rocks, the Ordovician and the Silurian, crop out along the axis of the anticline. As these older systems dip off to lower levels to the east, successively higher and therefore younger systems, appear at the surface and in turn dip eastward beneath younger strata. The same relations exist to the west of the axis but that is largely beyond the state boundary.

A column of principle rock formations exposed in Ohio is shown in Table II, grouped by systems. The three lower systems, Ordovician, Silurian, Devonian, are dominantly limestone. The three higher systems, Mississippian, Pennsylvanian, Permian, are dominantly sandstone and shale.

TABLE II

PRINCIPAL ROCK FORMATIONS OF OHIO

	Thickness Feet
Permian system	
Green sh.—ss. (many members)	400
Washington sh.—ss. (many members)	225
Pennsylvanian system	
Monongahela sh.—ss.—ls.—coal (many members)	250
Conemaugh sh.—ss.—ls. (many members)	400
Allegheny sh.—ss.—ls.—coal (many members)	200
Pottsville sh.—ss.—ls.—coal (many members)	250

Mississippian system	
Maxville ls.	25
Logan sh.—ss. (three members)	200
Cuyahoga sh.—ss. (three members including Black Hand)	300
Sunbury sh.	25
Berea ss.	50
Bedford sh.	75
Devonian system	
Ohio sh. (three members).	600
Olentangy sh	35
Delaware ls.	35
Columbus ls.	90
Detroit River dol. (four members).	200
Sylvania ss.	40
Silurian system	
Bass Island dol. (four members including Put-in-Bay)	300
Cedarville dol.	200
Springfield dol.	10
Euphemia dol.	10
Osgood sh.	35
Dayton ls.	10
Brassfield ls.	35
Ordovician system	
Richmond sh.—ls. (several members)	275
Maysville sh.—ls. (several members)	200
Eden sh.—ls. (several members)	200
Cynthiana sh.—ls. (several members)	100

The exposed bedrocks of Ohio are all sedimentary rocks, that is made from sediments, deposits such as clay, sand, calcareous ooze, laid down in shallow marine seas which covered the region that is now Ohio, and later cemented to form solid bedrock.

That division of geology which treats of the surface features of the earth and their interpretation is known as geomorphology. In the language of the geomorphologist the interpretation of surface features is based on structure, process, and stage.

Structure includes the rock material; its resistance, its stratification and jointing, as well as the position of the rock strata, whether horizontal, inclined, folded or faulted.

Process refers to the processes which are working upon the rock materials and thereby producing changes in the surface features. These processes are weathering, erosion, degradation, aggradation. They are the work of dynamic agents such as running water in streams, moving ice in glaciers, wind.

Stage is concerned with the extent to which the change has progressed as compared with the final condition that can be attained by the work of the process involved. It is based upon the principle that a process or set of processes affecting a particular region will change the relief features in an orderly way from one set of characteristics to another set of characteristics until finally the region is brought to a condition in which the agents involved can produce no further changes. The cycle has then been completed. The characteristics of the relief features of the various stages of the cycle are distinctive and thereby determine the stage in the cycle. For most geomorphic cycles the stages are designated by the very general terms of youth, maturity, and old age as based on characteristics and not on actual length of time.

The idea of cycle may be illustrated by the stream-erosion cycle using the diagrams shown in Figure 2. A relatively level surface at considerable elevation

above sea level is dissected by a set of streams. Downcutting is rapid, resulting in deep, narrow, steep-walled valleys. Between the valleys are broad level upland areas as yet undissected. The region is in the youthful stage of the stream-erosion cycle (Fig. 2, B, C).

Finally, the streams cut down, to or near to base level which is determined by the level of the body of water into which they drain. The stream gradients become gentle, the rapids and falls have been destroyed, and downcutting stops. Valley widening continues, the valley slopes become gentler, and the upland flats become narrower until only ridges remain. All the surface is now in slopes. The dissection is complete. The region is in the mature stages of the erosion cycle (Fig. 2, D).

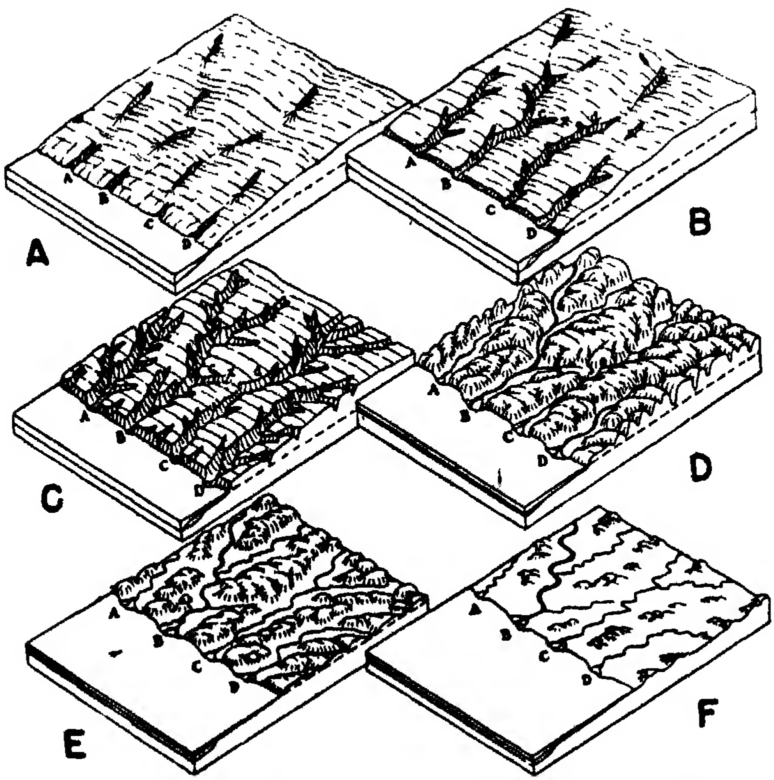


Fig. 2. Set of block diagrams showing changes in topography during the stream-erosion cycle from youth to old age. (Reprinted by permission from *Outlines of Physical Geology*, by Longwell, Kropf, and Flint, published by John Wiley and Sons, Inc.)

Further erosion lowers the divide ridges making the valley slopes still gentler, floodplains develop and increase in width, until all the region has been lowered to the lowest possible level, the base level of stream erosion, an even, lowland plain. The region has reached the old age stage of the stream-erosion cycle, and no further stream erosion may take place. The cycle has been completed (Fig. 2, F). During the process of stream erosion, the region has passed from a level upland plain, to a rugged, completely dissected country all in slopes, and finally again to an even plain but at a lowland level. This is the history and the fate of every region upon which rain falls and which has sufficient elevation above sea level.

The locations of a number of the scenic features or interesting relief features of Ohio are shown on Figure 3. These features are of various types and origins. The largest number has resulted from the work of running water; others from the work of ground water; others from glaciation. Only a few of these can be treated in

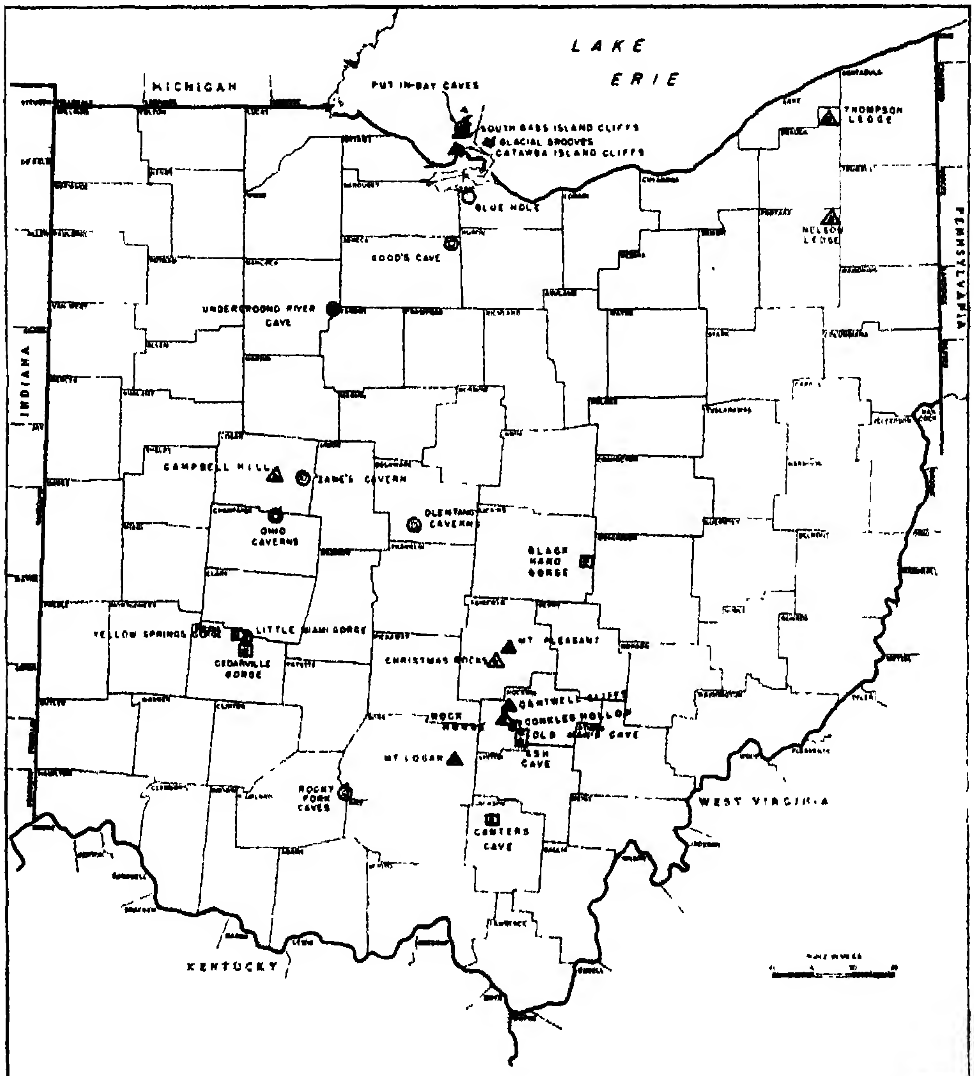


Fig. 3. Map of Ohio showing the location of scenic features.

this paper for it seems that our purpose can be better served by a full treatment of a small number than by a more general treatment of a large number. We will treat first a group located in northern Greene County, second a group in western Hocking County, and third Lake Erie and the islands.

GORGES OF GREENE COUNTY

In northern Greene County, about 10 miles south of Springfield, there are three rather notable steep-walled gorges located respectively near the villages of Clifton, Yellow Springs, and Cedarville, all within a radius of three miles (Fig. 4). The largest, most prominent one of these is Clifton gorge and this one will be treated as an example of the group. It illustrates admirably the relation of the form of the valley to the several rock formations in which it is cut.

Clifton Gorge is part of the Little Miami River Valley, located west of the village of Clifton (Fig. 4). Northeast of Clifton the Little Miami flows in a very broad, upland valley cut in glacial drift as shown in unit 1 of Figure 5. It served as an outlet for the melt waters of a considerable section of the glacier front to the north and east and its broad valley floor is underlain by gravel. Except for its greater width it is a typical stream valley of the glacial region of central Ohio.

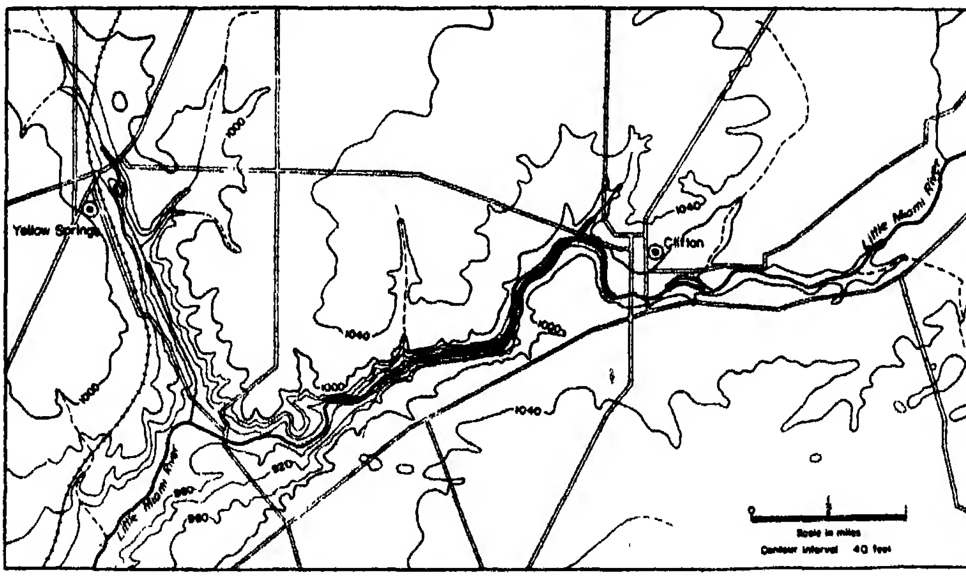


Fig. 4. Map of the Little Miami River Valley in the Clifton-Yellow Springs region.

Just east of Clifton the river reaches the bedrock and the valley deepens rapidly so that in half a mile downstream at the west edge of the village, the valley is about 50 feet deep and has a cross section as shown by unit 2 of Figure 5. The gradient of the river is steep and its work is almost entirely downcutting. The valley sides are steep to overhanging and the valley width is little more than the width of the stream (Fig. 6). It is a typical youthful valley formed by rapid downcutting in a massive rock of uniform resistance.

Just west of the bend west of the village the river drops into a narrow, winding channel and plunges down by a series of rapids for a drop of 20 to 30 feet in a distance of about 50 yards (Fig. 7). The channel is only 5 to 10 feet wide and 10 to 20 feet deep and is cut in the bottom of an outer gorge which in cross profile is a continuation of unit 2. The narrow, twisting channel has apparently been made by enlarging and connecting a series of potholes. This is unit 3 of the cross sections of Figure 5.

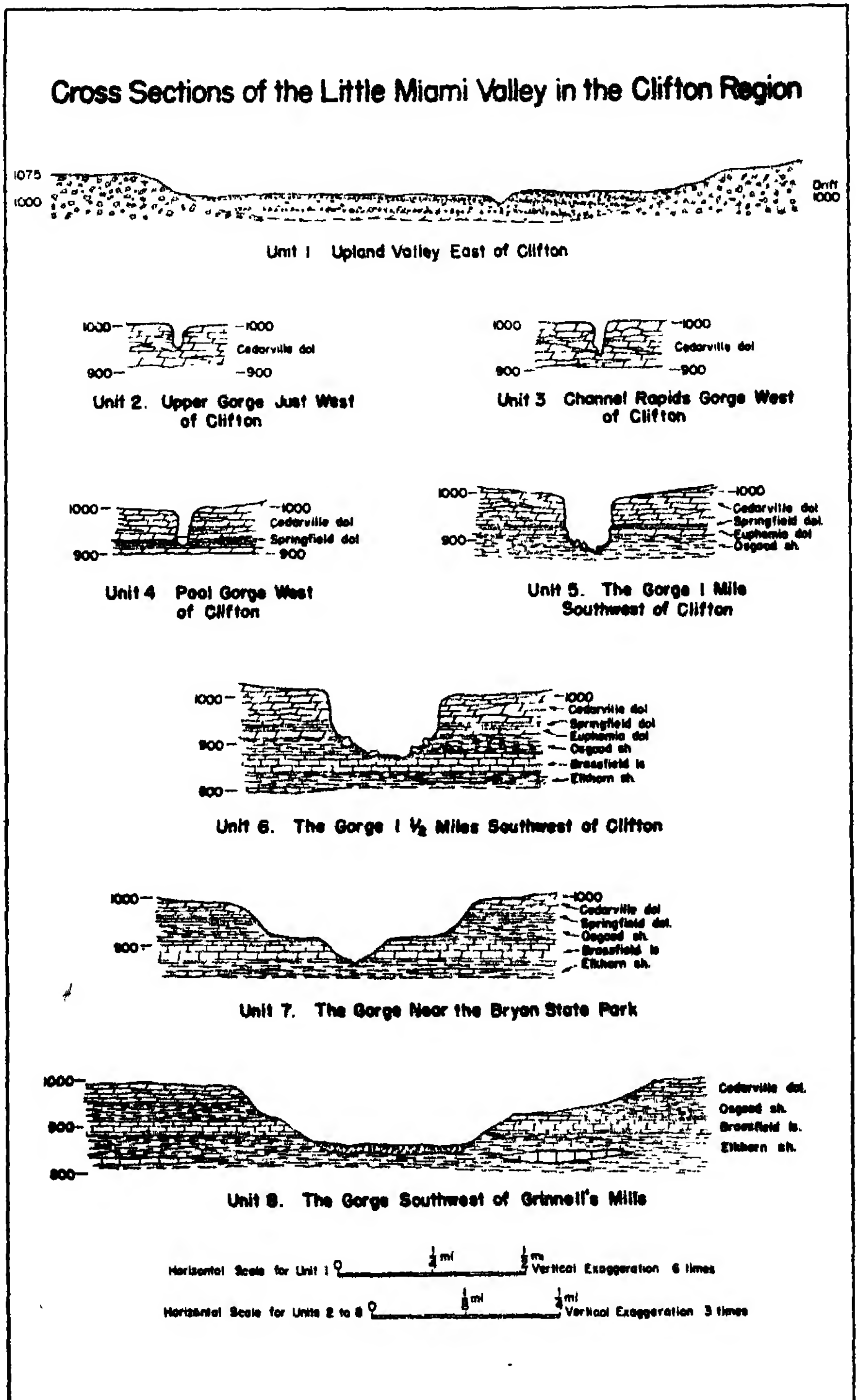


Fig. 5. Cross sections of the Little Miami River Valley in the Clifton region.

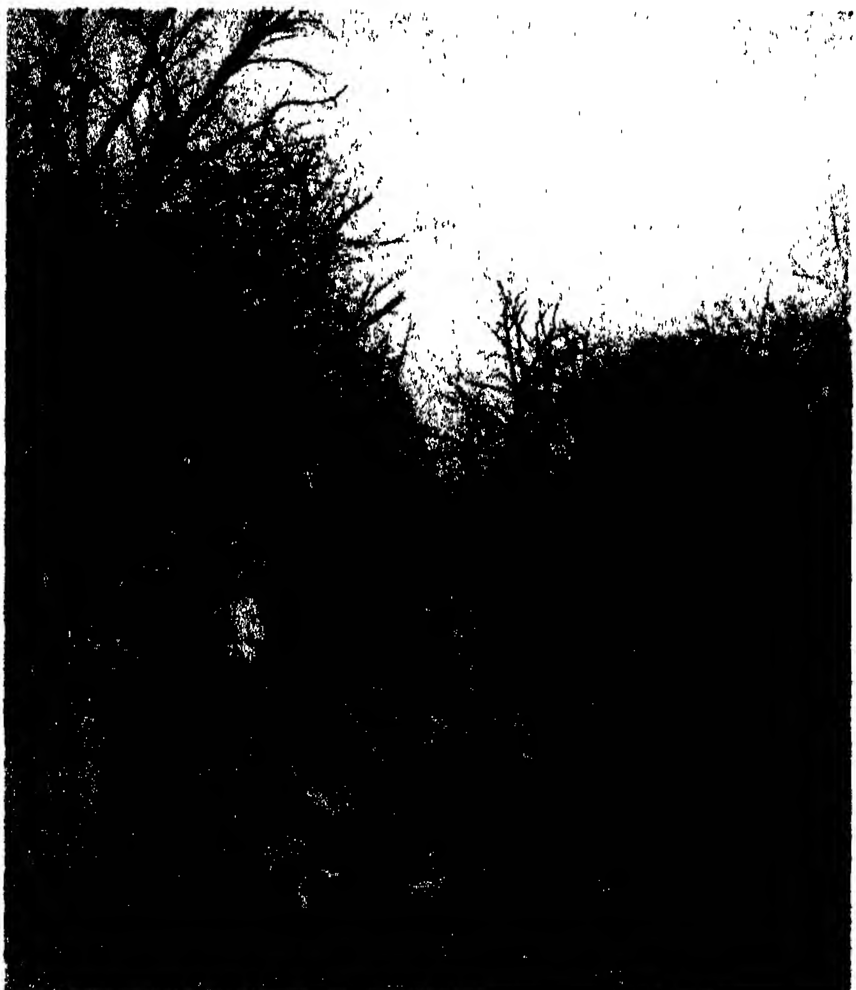


Fig. 6. The upper part of the Little Miami Gorge just west of Clifton.

Fig. 7. View looking up the Channel-Rapids Gorge from the upper part of the Pool Gorge. The Little Miami River just west of Clifton, (Ohio Development and Publicity Commission).

The water next enters a pool and flows quietly for about 200 yards in a narrow gorge 60 to 70 feet deep, and only 50 to 60 feet wide, with vertical or overhanging walls. This is unit 4 of Figure 5. It has a width similar to that in unit 2, and the upper, outer part of unit 3 but it is deeper and the walls rise direct from the water level of a quiet pool which fills the entire width of the gorge.

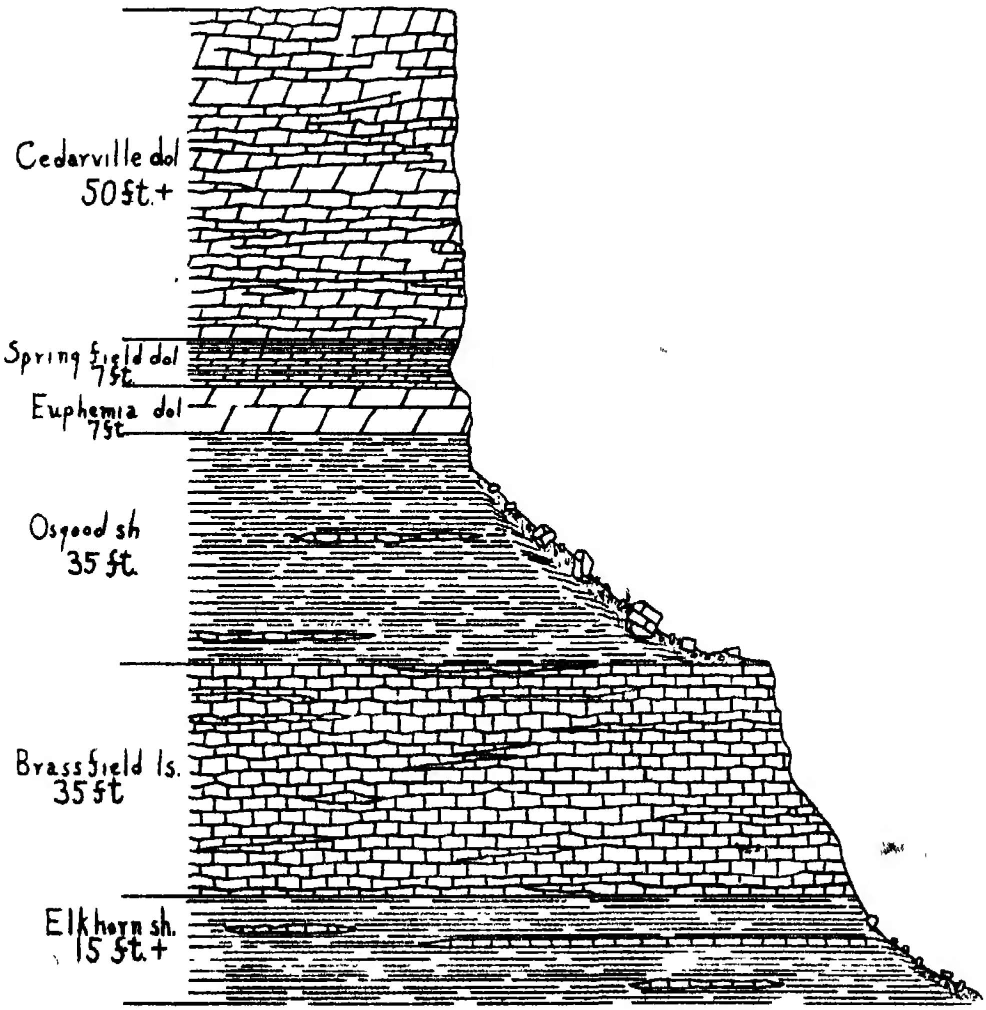


Fig. 8. Columnar section of the rock formations of the Little Miami River Gorge.

All the rock exposed in the gorge through units 2, 3, and 4, is massive, porous dolomite in ledges 5 to 10 feet thick. It is known to geologists as the Cedarville dolomite and is shown as the highest unit of Figure 8. It commonly forms bold, vertical cliffs and narrow gorges with high-gradient streams. Next below the Cedarville is the Springfield dolomite, 5 to 10 feet of bedded stone in even layers 4 to 10 inches thick (Fig. 8). It is less resistant than the Cedarville and at places weathers out forming a slight reentrant beneath the Cedarville cliff. Next below

is the Euphemia dolomite, 5 to 10 feet of thick-bedded stone (Fig. 8). It is more resistant than the Springfield and at places forms a slight shoulder on the slope. At places both the Springfield and the Euphemia unite with the thicker Cedarville above in one great cliff face.

Below the Euphemia is about 40 feet of soft, blue shale, with a few layers of shaly limestone, known as the Osgood shale (Fig. 8). This unit weathers readily, and slumps away on the valley side leaving the dolomite above insufficiently supported so that the Euphemia and higher dolomites break off in great blocks that fall onto, and become part of the talus slope below, which covers the outcrop of the Osgood shale. By this method of slumping away of the shale, and the falling away of the unsupported dolomite, the cliff faces retreat and the valley is widened at the level of the shale.

Below the Osgood is the Brassfield limestone, a firm, bedded stone about 30 feet thick (Fig. 8). Where the river has cut into the Brassfield limestone, there is an inner narrow valley or gorge and the river gradient is steep.

Beneath the Brassfield limestone should be the Elkhorn, a soft, clay shale which weathers readily (Fig. 8). It is not exposed in the gorge, but its presence is plainly indicated by the broader valley floor down stream from the ouctrop of the Brassfield.

Returning to the Pool Gorge of unit 4 it may now be noted that the base of the massive Cedarville dolomite is at or just below the water level of the pool (Fig. 5, unit 4) and that the basin occupied by the pool was dug out from the underlying less resistant, thin-bedded Springfield dolomite. This allowed the Cedarville dolomite to break off along vertical joints to form such vertical gorge walls as shown in Figure 9 with a reentrant at the base made by the wearing out of the less resistant thin-bedded Springfield dolomite.

Continuing down stream from the Pool Gorge, unit 4, the valley broadens gradually and becomes deeper to 100 feet and ultimately to 150 feet (Fig. 5, unit 5). The upper 40 to 50 feet of the bluff is a cliff of massive Cedarville dolomite and below this is a steep talus slope with large loose blocks of Cedarville, down to river level (Fig. 10). Many of the blocks are of enormous size, up to 20 to 30 feet across and many of them lie with the bedding planes at various angles. One great block, known as "Steamboat Rock" and shown as Figure 11, stands in the middle of the river with the bedding planes in a vertical position. The river is cutting at some level in the Osgood shale and downcutting and valley widening are rapid.

This unit 5 of the valley has a length of about half a mile. It is a region of distinct scenic beauty as well as geologic interest. The bluffs of massive dolomite; the fern-covered talus slopes with great projecting blocks of stone; the rapid flowing stream; the tall treees rising straight toward the sunlight above the gorge; all combine to form a scenic feature which is unsurpassed in western Ohio.

Another considerable section of the gorge is represented by unit 6 of Figure 5. It differs from unit 5 chiefly in that the downcutting river has here reached the top of the more resistant Brassfield limestone, and has carved out a broader valley floor near the stream level on the top of the limestone. Also the valley as a whole is broader and the talus slopes longer and gentler.

Farther down the valley the river has cut into the Brassfield limestone forming an inner, relatively narrow, steep-sided valley as shown in unit 7 of Figure 5. At the top of the Brassfield there is a narrow rock bench, the rock floor level of unit 6. Above this on the outcrop of the Osgood shale, is the usual talus slope with blocks of dolomite from above. The Cedarville dolomite, here reduced to 10 to 20 feet thickness, forms the usual bold vertical cliff capping the valley slope.

Farther down the valley, near the mouth of Yellow Springs Creek, the Little Miami Valley floor widens to about one-fourth of a mile, as shown in unit 8 of Figure 5. Here the river has evidently cut through the Brassfield limestone and

Fig. 9. Bluff of Little Miami Valley at the downstream end of the Pool Gorge. The cliff is Cedarville dolomite and the reentrant at the base is caused by the wearing out of the less resistant Springfield dolomite.

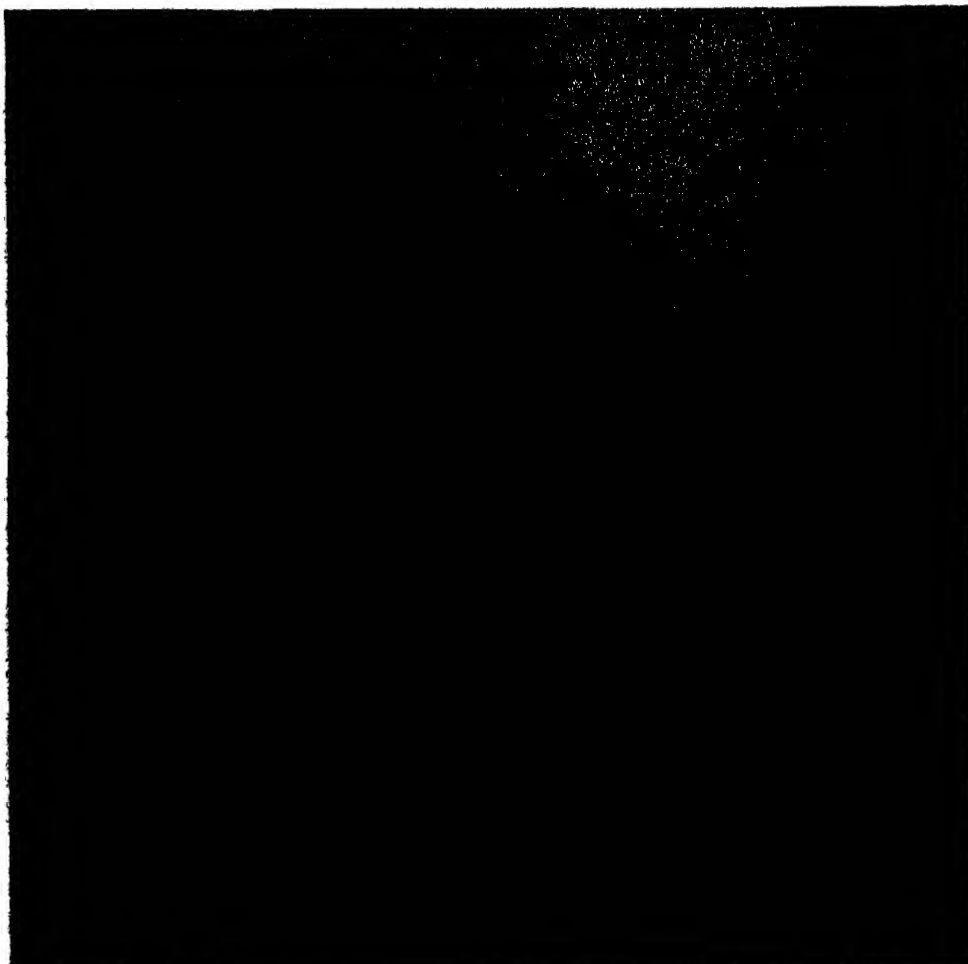


Fig. 10. The Little Miami River in Clifton Gorge showing blocks of massive Cedarville dolomite that have fallen from the cliffs above. (Ohio Development and Publicity Commission.)

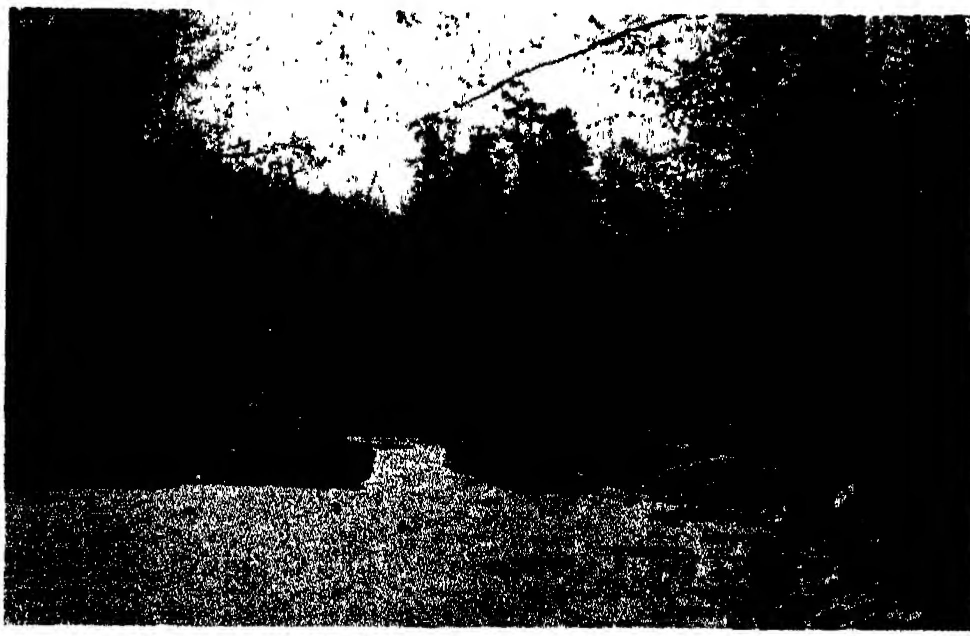


Fig. 11. "Steamboat Rock" on the Little Miami River in Clifton Gorge. A block of Cedarville dolomite with bedding planes in a vertical position.

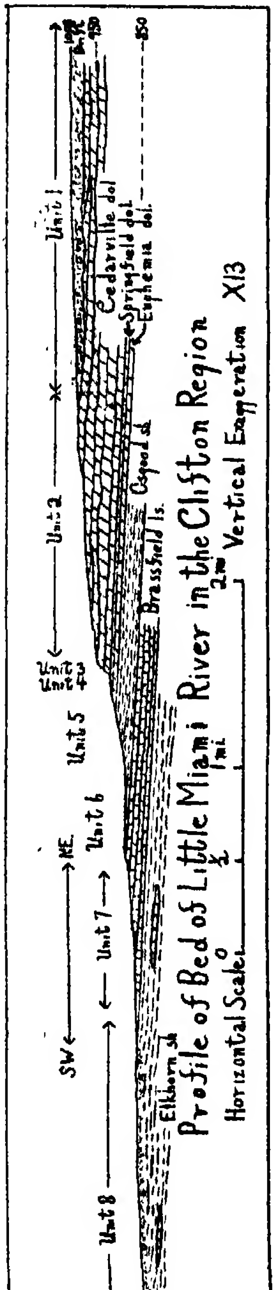


Fig. 12. Longitudinal section and profile of bed of Little Miami River in the Clifton region, showing the relation of the gradient of the stream to the bedrock material.

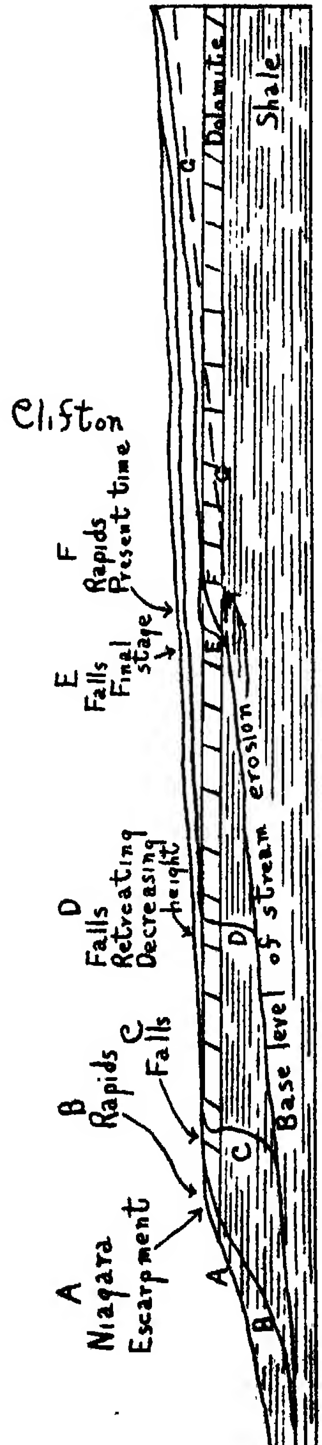


Fig. 13. Longitudinal section and profile along the Little Miami River showing successive stream profiles during the origin, retreat and disappearance of the falls.

widened the valley in the horizon of the Elkhorn shale, although no exposures of the Elkhorn are known for several miles farther down the valley. The steeper slope above is on the outcrop of the Brassfield limestone. The bench and gentler slope next above are on the outcrop of the Osgood shale. The steeper slope at the top of the valley wall is on the outcrop of the higher dolomites.

There is also a close relation of the profile of the river bed to the underlying rock materials as shown in Figure 12. Unit 1 is on the upland where the river flows with gentle gradient on glacial drift. In unit 2 the river is flowing on the Cedarville dolomite and the valley is deepening rapidly. Unit 3 is the rapids by which the river crosses the lower part of the Cedarville dolomite down into the plunge basin of unit 4 carved out of the underlying Springfield dolomite. In unit 5 the river has a steep gradient down across the soft Osgood shale to unit 6 where the gradient is gentle, held up on the top surface of Brassfield limestone. Unit 7 has a steeper gradient across the Brassfield and unit 8 has a gentle gradient in the Elkhorn shale. The longitudinal profile and the cross profile of the valley in each unit is determined by the nature of the rock.

About three miles west of Clifton near the village of Yellow Springs is Yellow Springs Gorge which is part of the valley of Yellow Springs Creek (Fig. 4). This creek heads out on the glacial plain to the north where it flows in a broad open valley cut in glacial drift. Near the village it reaches the bedrock and descends, by a waterfalls on the Cedarville dolomite, into the head of the gorge which leads southward for about two miles, where Yellow Springs Creek joins the Little Miami River just west of the lower end of Clifton Gorge. The main characteristics of Yellow Springs Gorge and rock units exposed are quite similar to those of Clifton Gorge but less rugged and picturesque.

Small units of Yellow Springs Gorge and of Clifton Gorge are now in parks under various forms of management. The entire two gorges, including the place where they unite, should be acquired by the state in order to preserve this most outstanding scenic feature of western Ohio and make it better available for visit by the public.

The explanation of the origin and the location of these gorges and water falls is connected with certain regional geologic relations of southwestern Ohio and adjoining states which are shown on Figure 14. There is here an elliptical area of Ordovician rocks surrounded by a band of the overlying and therefore younger Silurian rocks. The Ordovician outcrop is on the axis of the Cincinnati anticline and the rock strata dip gently away from the Ordovician to the east and to the west down the flanks of the anticline and also to the north on the plunging axis of the anticline. These relations in so far as southwestern Ohio is concerned are more exactly shown in Figure 15 which gives the distribution of the Ordovician and Silurian systems and the location of the gorges near Clifton in the western part of the Silurian band, that is in the lower part of the Silurian rock section.

The map also shows the drainage pattern of the region, the chief feature being that the streams flow from the northeast, north and northwest and converge toward Cincinnati. This means that the general slope of southwestern Ohio is toward Cincinnati. The streams flow from Silurian to Ordovician, that is from younger to older rocks and opposite to the direction of dip of the strata.

The Ordovician rocks consist of shale and thin beds of limestone and are less resistant than the Silurian rocks which consist largely of thick-bedded or massive limestone or dolomite. The area of less resistant Ordovician rocks, being in the down-stream part of the drainage system, has been worn to a lower level, and to a more rugged topography, than the Silurian area of more resistant rocks on the headwaters region. Where the two area border, there was thus developed a narrow belt with a steeper slope descending from the Silurian area to the Ordovician area as shown in Figure 15. This is an indistinct escarpment slope on the edge of the

Silurian rocks. Since the Silurian rocks dip gently away from the Ordovician area, erosion has developed something of a cuesta form with an undercut-slope facing the Ordovician and a dip-slope toward the Silurian area. Stream erosion

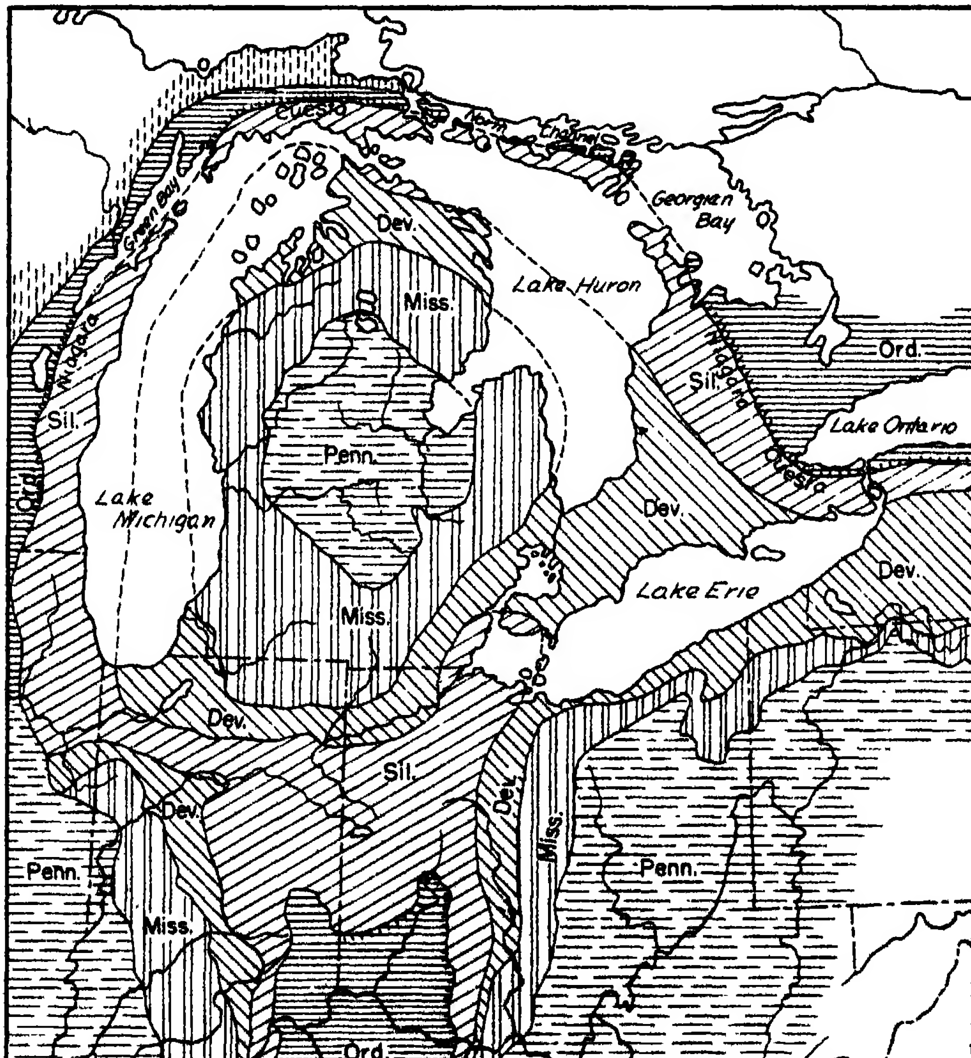
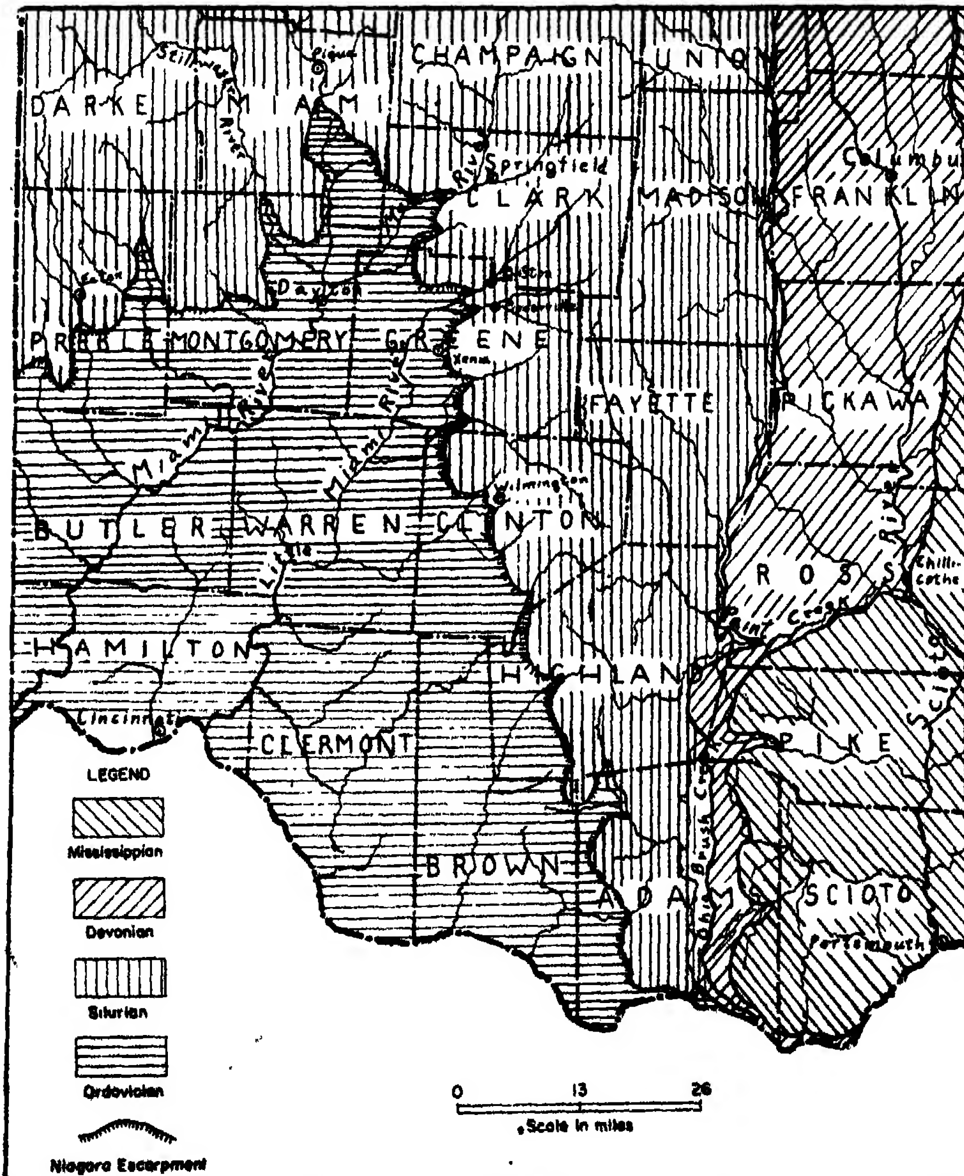


Fig. 14. Geologic map of the Eastern Interior region showing the distribution of rock systems and the course of the Niagara Escarpment.

has made the course of the escarpment irregular (Fig. 15) and the details of this cuesta feature are largely hidden by the mantle of glacial drift that covers the region.

When the glacial ice melted off the surface of southwestern Ohio a southwestward flowing stream came into existence along the present course of the Little



drainage.

Fig. 15. Geologic map of southwestern Ohio showing the distribution of the rock systems, the course of the Niagara Escarpment, and the drainage.

Miami River past Clifton. About four miles southwest of this village the stream passed from the higher surface on the more resistant Silurian dolomites down the escarpment to the lower surface on the less resistant Ordovician shales as shown in Figure 13. The faster down cutting on the shale produced rapids (Fig. 13, profiles A and B) and when the stream bed on the softer shale was worn below the base of the resistant dolomite a waterfalls resulted (profile C). The plunge of the water over the falls wore out the softer shale beneath the edge of the dolomite, and inadequately supported blocks broke off and fell away. This resulted in the gradual retreat of the falls upstream (profiles C and D) and the formation of a gorge in that portion of the valley along which the falls retreated. Since all stream beds must rise upstream, the falls gradually decreased in height to the place where the stream bed rose to the base of the resistant dolomite (profile E). No longer could undercutting or sapping of the cap rock take place. The lengthening of the gorge by the process of the retreat of the falls was ended. This condition was reached for the Little Miami in unit 4, the Pool Gorge. With further erosion the falls became a rapids (profile F). This is unit 3, the Channel Rapids of the present valley (Fig. 7). The rapids is the stage that follows next upstream from where a falls stops retreating. It carries the water from the level of the valley floor above the falls across the thickness of the resistant rock unit that caused the falls. Downcutting is rapid and in course of time even the rapids will be reduced to an even gradient as shown in profile G of Figure 13. That is, in the old age stage of the cycle all irregularities of the gradient of the stream bed due to differential hardness of the rock will have been worn away.

In both the Yellow Springs and the Cedarville gorges the level of the stream at the base of the falls is approximately at the base of the Silurian dolomite and the upstream retreat of the falls will soon cease. With further erosion the falls will become rapids and these will gradually be worn away. This is the history through which all the streams which flow from the Silurian rock areas of southwestern Ohio to the Ordovician rock area have passed.

It is probable that the Little Miami River took its present course across the escarpment with the disappearance of the last ice sheet, the Wisconsin, usually estimated as about 30,000 years ago. During this time the falls has retreated a distance of approximately four miles at an average rate of about nine inches per year.

Similar, but less prominent gorge-like valleys exist to the northwest and west wherever streams across the irregular outcrop of the Cedarville dolomite from Greene County to the Indiana line (Fig. 15). Also to the south of the Clifton region in Greene, Clinton and Highland Counties the valleys become more sharply cut where they cross from the Silurian rocks to the Ordovician.

The escarpment described above is, in topography, in structure, in lithology, and even in the geologic age of the rocks similar to the east-west escarpment of western New York, known as the Niagara escarpment (Fig. 16) and they have had similar effects in the development of gorges and waterfalls.

The Niagara escarpment extends in a curving course from central New York westward through southwestern Ontario, northern Michigan, and eastern Wisconsin, a distance of several hundred miles as shown on Figure 14. Throughout this distance the Niagaran dolomites dip toward the Michigan Basin and form a cuesta ridge with a steep front to the north, northeast or northwest and a gentler slope to the south. Parts of this cuesta are the Niagara escarpment of western New York and southwestern Ontario; the Bruce peninsula; Manitoulin and Drummond islands; a partly buried cuesta ridge in northern Michigan; the Escanaba and Door peninsulas east of Green Bay; and a partly buried, westward-facing cuesta ridge in eastern Wisconsin. Bordering this long elevation, on the north is a long depression worn out on the outcrop band of the Ordovician shales. The

lowest parts of this depression form the basins of Lake Ontario, Georgian Bay, North Channel, Green Bay, Lake Winnebago, and the low course followed by the headwaters of Fox River southward in eastern Wisconsin. It is a notable illustration of the influence of rock materials and rock structure in the origin and location of large relief and geographic features.

When the melting of the Wisconsin ice sheet freed the surface of western New York the overflow waters of Lake Erie escaped northward along the course of the present Niagara River (Fig. 16) across a plain underlain by Silurian rocks and dropped off the northward facing escarpment capped by the Niagara dolomites

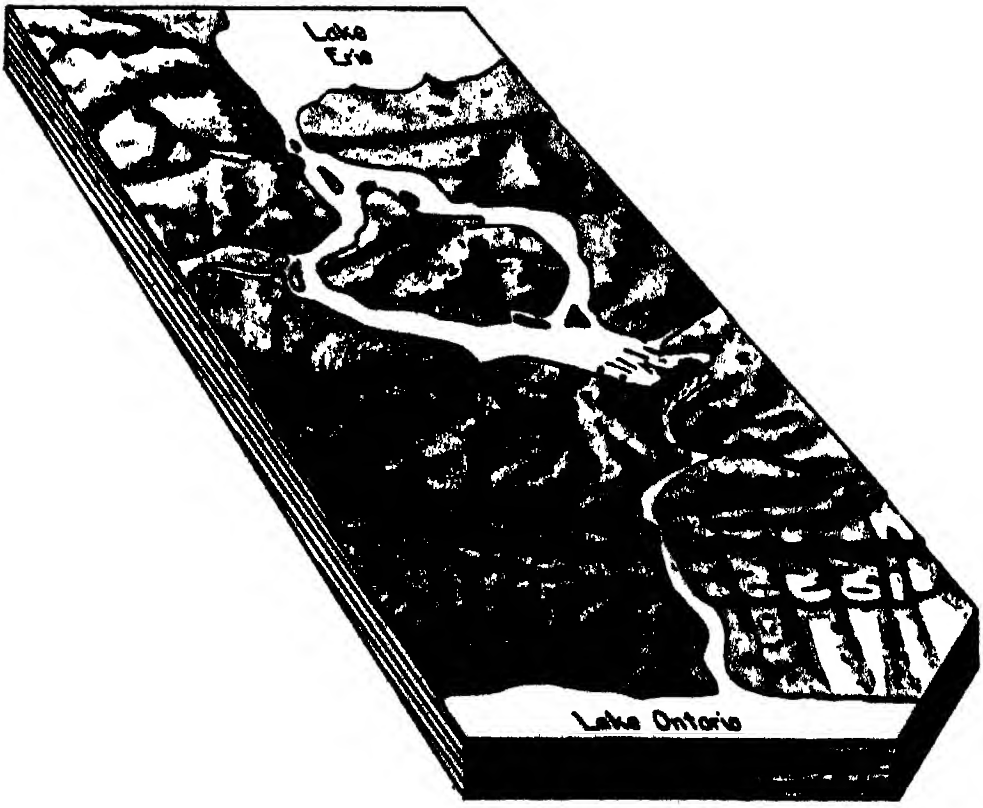


Fig. 16. Bird's-eye view of Niagara River and Falls, looking south. Greatest length of block, 35 miles. Vertical exaggeration, 2 times. (Reprinted from *Outlines of Physical Geology*, by Longwell, Knopf, and Flint, published by John Wiley and Sons, Inc.)

to the lower, Ontario plain underlain by Ordovician shales. The waterfalls thus formed at the face of the escarpment began to retreat upstream by sapping and the fall of the unsupported cap rock, and the Niagara gorge was started. The retreat has continued until now the falls is seven miles from the escarpment where it started, leaving behind the magnificent Niagara gorge. But unlike our Ohio Niagaras there is still plenty of drop and the falls will continue to retreat, and the gorge to lengthen, until perhaps Lake Erie is reached and drained. Lakes and waterfalls are characteristic of the youthful stage of the erosion cycle. Both are short lived features, geologically speaking.

HOCKING COUNTY PARK REGION

In southwestern Hocking County east of Laurelville there are several well known scenic features the locations of which are shown on Figure 17. Of these Ash Cave, Cedar Falls, Old Man's Cave, Conkles Hollow, Rock House, and Cantwell Cliffs are now included in small State Forest Parks. This is a rugged region with a relief of 300 to 400 feet, near the western edge of the Appalachian Plateau.

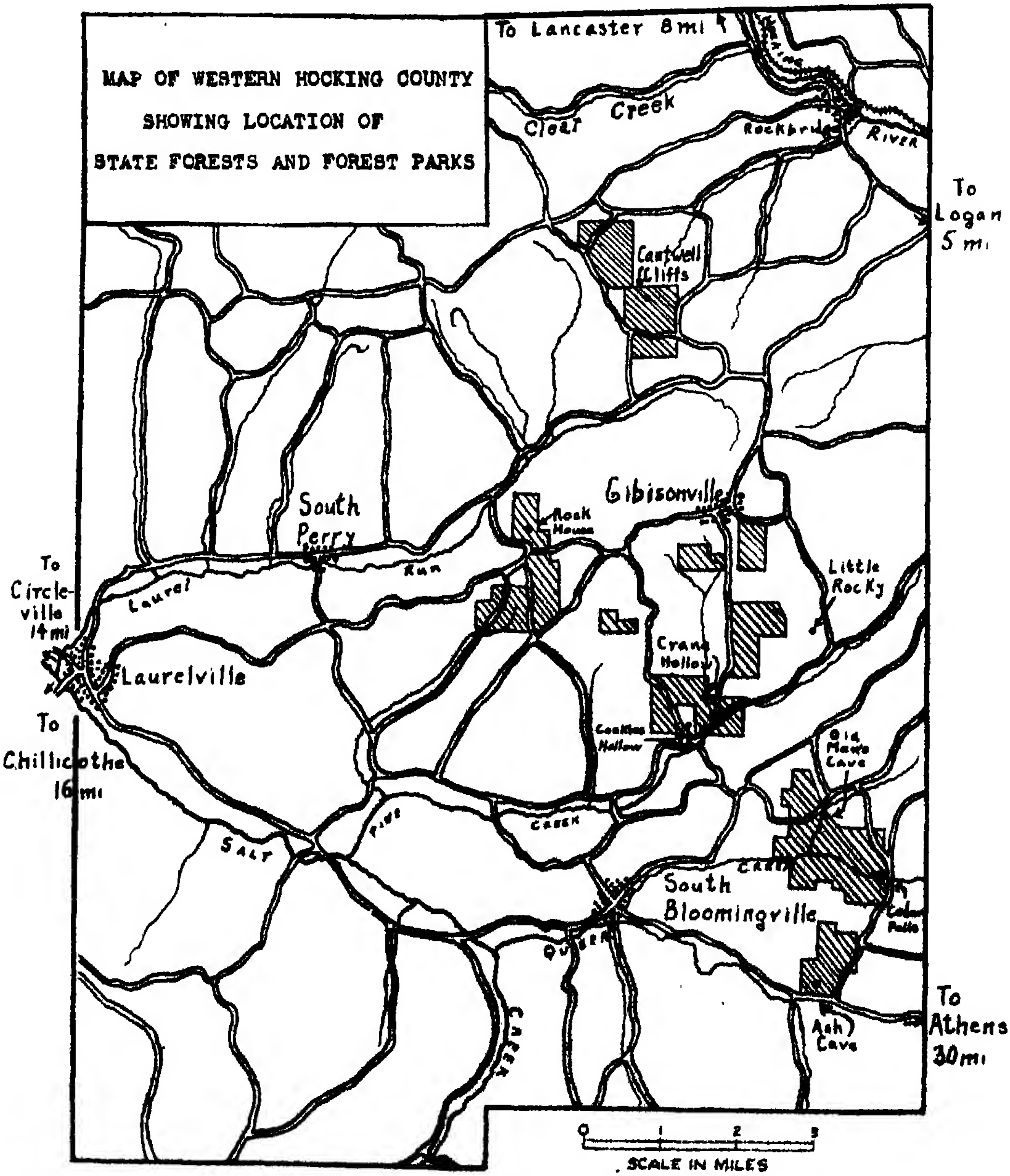


Fig. 17. Map of western Hocking County showing location of state forests and forest parks.

The chief scenic features are narrow, steep-walled gorges which terminate headward in steep-walled, ampitheater-shaped pockets or coves; waterfalls which plunge into these valley heads from projecting ledges above; and rock shelters or re-entrants in the valley walls beneath projecting ledges commonly called caves. All these features are the result of weathering and the erosive work of running water on rocks of differential hardness.

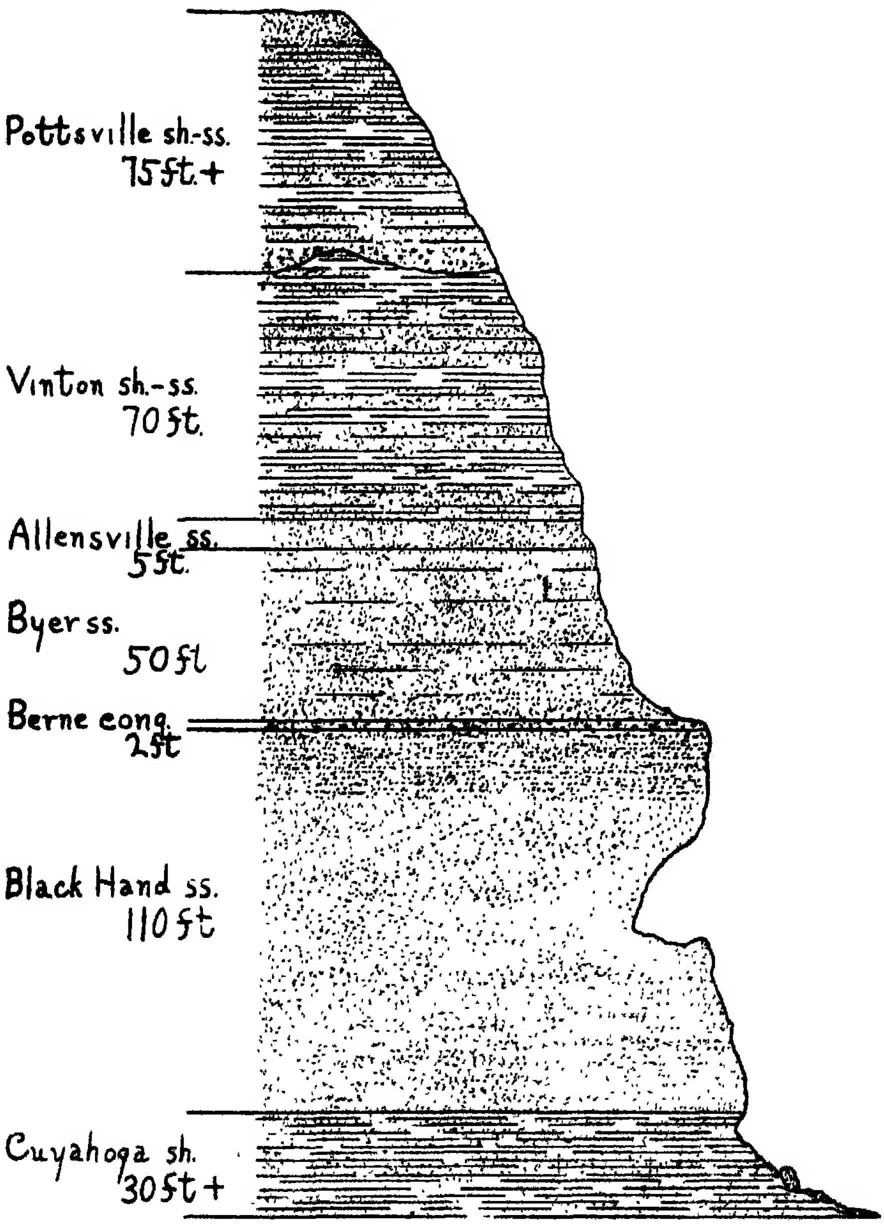


Fig. 18. Columnar section of the rock formations of Western Hocking County.

The rock strata of the region consist of sandstone and shale as shown in Figure 18. The most important unit in the development of scenic features is the Black Hand sandstone, a thick-bedded, massive, resistant, pebbly sandstone 100 to 150 feet thick. If forms the walls of the gorges, causes most of the waterfalls, and in it the valley-side caves are developed. The upper 15 to 20 feet of the sandstone is horizontally-bedded and quite firmly cemented. Lower down, the middle part of the formation is cross-bedded and less firmly cemented. This results in more rapid disintegration of the middle part of the Black Hand and the development of a somewhat projecting upper part of the cliff.

Locally, in this cross-bedded middle part considerable reentrants have developed in the valley walls forming the features called caves, of which Old Man's Cave and Ash Cave (Fig. 19) are the largest and best known. They commonly have a floor on firmer stone below; are semicircular or semielliptical in plan; and half dome shaped with the apex above the middle of the outer edge. Ash Cave has a length of about 500 feet along the face of the cliff; a height of about 80 feet at the top of the dome, and a reentrant depth of about 100 feet at the floor level. These reentrants are believed to be due chiefly to more rapid disintegration locally of the cementing material of the sandstone allowing the grains to fall away. Blocks of sandstone that have fallen from the roof are present, but not numerous. The removal of the sand grains that fall to the floor of a cave may be accomplished by the wind or by the runoff of such rainfall as may be blown into the cave.

It should be noted that these are not true caves; a term that should be reserved for underground caves and passageways developed in limestone rock by solution by ground water. These features are simply reentrants in cliff faces and open out widely to the valley sides. A better name is rock shelter or rock-shelter cave.

Reentrants in the cliffs at the heads of the gorges are in part due to sapping by development of the plunge basin beneath the waterfall, and there are commonly here great blocks of sandstone that have fallen from the projecting ledge above. There should also be here greater decomposition due to the continually moist condition of the cliff from the spray of the waterfall. The sapping action here is important in causing the headward growth of the gorge. It is the usual method of retreat of waterfalls (Fig. 19).

The rock strata of the region dip gently to east as shown in Figure 20. Just west of this park area the Black Hand conglomerate terminates along an irregular, westward-facing escarpment, and the land surface drops down to lower elevation and lower rock units. This is the west edge of the Appalachian Plateau, which here is along the undercut slope of a low angle cuesta on the Mississippian sandstone, particularly the Black Hand sandstone. The drainage is westward so that in general the streams go from the higher upland on the east across the outcrop of the Black Hand to the lower surface to the west or to some valley, the level of which is conditioned by this lower surface. Rapid trenching of the steep slope on the edge of the Black Hand produced waterfalls at some places, and their retreat headward has formed the steep-walled box canyons with ampitheater-shaped heads. Those in which the formative processes are still at work and in which the characteristics are especially well developed, or of large dimensions, are the scenic features.

Certain characteristic topographic features of the region, and their relation to the bedrock, may be shown by a short description and analysis of one of the valleys, such as the valley of Old Man's Creek shown in Figure 22. This creek is 3 miles long and flows southwest to its union with Queer Creek. Six rather distinct physiographic units can be recognized in this valley and are well shown in the longitudinal section and profile of Figure 21. Unit 1 is the headwaters, about half a mile long, and with a gradient at the rate of 250 feet per mile. This is a very typical upland ravine head for this region. Unit 2, 1¼ miles long has a gentle gradient of only 50 feet per mile. Unit 3 is a rapids and waterfall with a total

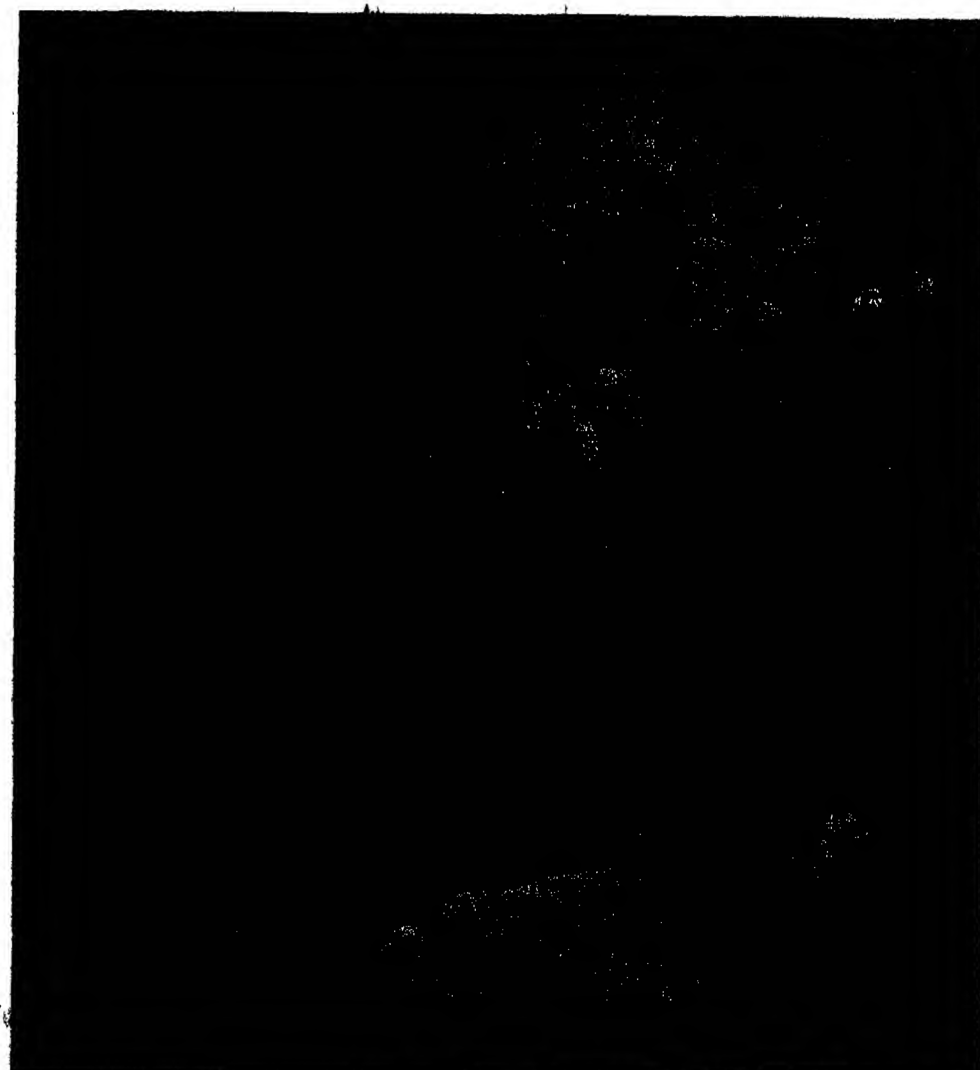


Fig. 19. View of the upper end of Ash Cave, the waterfall, and the plunge basin below. The firm, bedded sandstone forms the projecting cliff. The weaker, cross-bedded sandstone is in the upper part of the reentrant behind the falls, (Ohio Division of Forestry. Photo by Bob Wheaton).

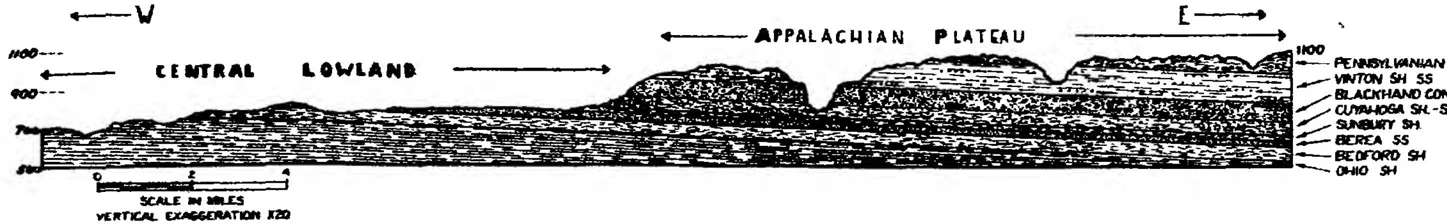


Fig. 20. West to east cross section of the Appalachian Plateau Front in Hocking County, showing the westward facing escarpment and the slight dip to the east.

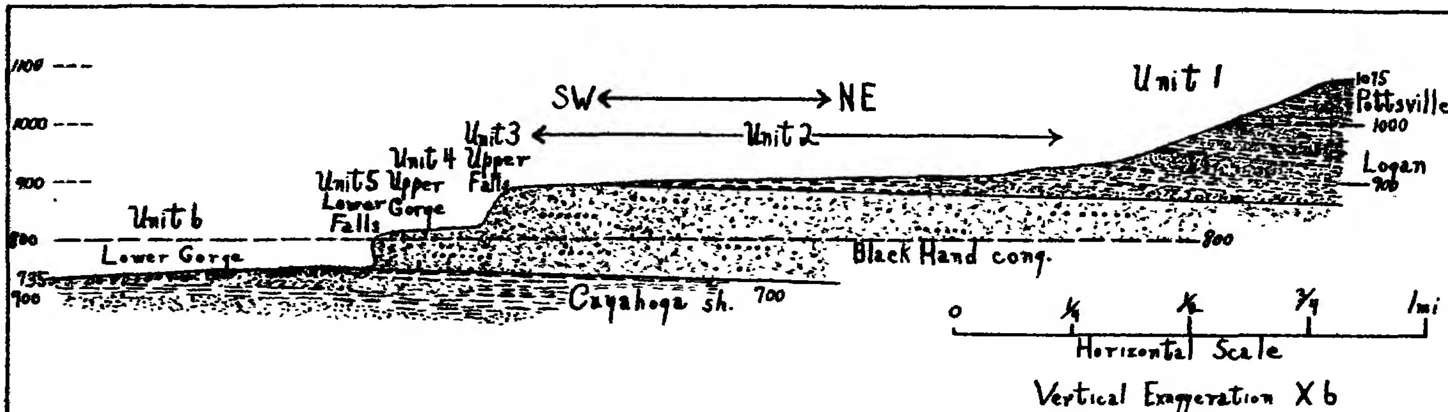


Fig. 21. Longitudinal section and profile along Old Man's Creek, showing the relation of the several physiographic units to the bedrock materials.

descent of 30 to 40 feet by which the stream drops into the head of the upper gorge. Unit 4 is this upper gorge about half a mile long. Unit 5 is the lower falls with a descent of 30 to 40 feet and unit 6 is the lower gorge over 100 feet deep and extending about 1 mile to the union with Queer Creek.

In Figure 23 cross sections of the valley are shown in units 2, 4, and 6. The valley of unit 2, above the gorge is broad and open, about 1 mile wide from divide to divide, 150 to 175 feet deep, and has a valley floor about 100 yards wide (Fig. 23, unit 2). The rocks in which this valley is cut consist of shale, sandy shale, and

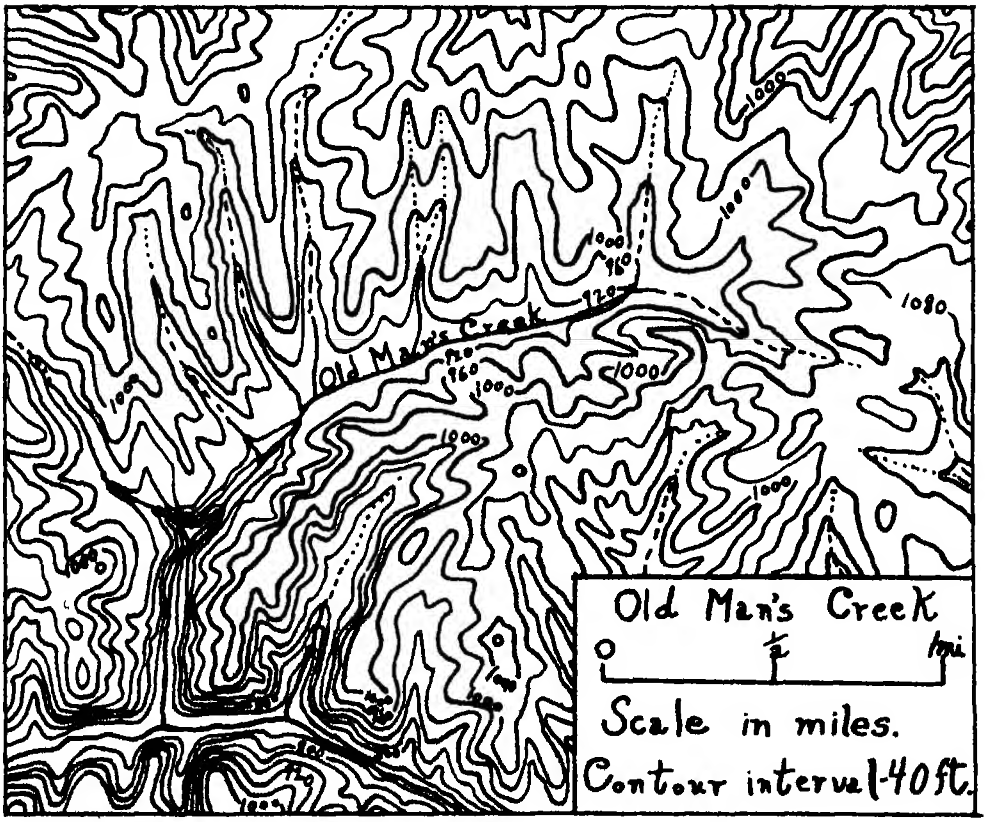


Fig. 22. Topographic map of the area drained by Old Man's Creek, Hocking County.

some sandstone. The floor of the valley is on or slightly above the top of the very resistant Black Hand sandstone, which, by acting as a temporary base level to retard the downcutting, has allowed the widening of the valley and the development of the gentle gradient of this unit. At the lower end of this unit the stream flows for 50 yards on a broad surface of the Black Hand sandstone without a channel as shown in the background of Figure 24. It then descends by a cascade (Fig. 24, foreground) and by a waterfall shown in Figure 25, the whole forming the Upper Falls, unit 3, by which the stream crosses the upper, more resistant part of the Black Hand and enters the head of the Upper Gorge.

Unit 4, the Upper Gorge, increases in depth from 30 to 40 feet near its head,

to 60 to 70 feet at its lower end and is cut in the less resistant, cross-bedded, middle part of the Black Hand sandstone (Fig. 23, unit 4). Above this inner gorge is a broad, higher or outer part of the valley with moderate slopes cut in shale and thin-bedded sandstone above Black Hand. This is simliar to the valley of unit 2. On either side of the valley just above the Black Hand is a narrow bench carved out on the upper surface of the Black Hand.

Next follows unit 5, the Lower Falls, shown in Figure 26, by which the water plunges down a twisting channel for 10 to 15 feet and thence falls to a plunge basin below for a total descent of 30 to 40 feet across the lower part of the Black Hand sandstone. At the level of the plunge basin beneath the overhanging ledge fine-grained shaly sandstone is exposed, the top of the next lower rock unit, the Cuyahoga shale.

Unit 6, the Lower Gorge, is over 100 feet deep (Fig. 23, unit 6). The vertical walls include practically the entire thickness of the Black Hand sandstone and the floor is probably in the underlying Cuyahoga shale but a great accumulation of loose material on the valley floor and against the base of the cliffs conceals the basal contact of the sandstone and any lower strata which may have been penetrated. Above the narrow, deep gorge cut in the Black Hand sandstone is the narrow bench or shoulder, and the broad outer valley above, cut in shale and thin sandstone beds. All of this shows a close relation of the form of the valley to the resistance of the rock material.

In the north wall near the lower end of the Upper Gorge, is the well known Old Man's Cave, shown in Figure 27. It is about 200 feet long, along the valley side, about 50 feet high at the top of the arch, and its greatest depth or overhang is about 75 feet. This cave, like the floor of the Upper Gorge, is at the level of the less resistant middle part of the Black Hand sandstone. This less resistant middle part has caused two falls instead of one and two sections of the gorge.

The foregoing has emphasized the contrast of the broad, outer, upper valley with gentle slopes as against the narrow, steep-walled inner gorge (see Fig. 23); the gentle gradient of the valley above the Upper Falls as against the steep gradient of the gorge (see Fig. 21); the falls by which the creek enters the gorge; and the bench on the valley side just above the inner gorge. All these are quite definitely related to, and seem to find adequate interpretation in, the greater resistance of the Black Hand sandstone as compared with the other rock units. If we apply the geomorphic analysis of structure, process, and stage, we find the process, that is stream erosion, is working on varying structure, that is differential hardness of rock units, which has resulted at this stage, in different valley forms according to the different hardness of the rock units.

In the northern part of the Hocking County Park region is a very unusual feature known as Rock House (see Fig. 17). Here is a great cliff of Black Hand sandstone up to 100 feet high forming the south wall of a valley shown in Figure 28. The cliff is quite direct and even, but with certain right angle offsets. At one place the rock mass sets out about 30 feet as shown in Figure 31 but the line of the cliff face is continued into this projecting mass by a tunnel-like passageway 20 to 30 feet wide, 20 to 25 feet high, and about 200 feet long, opening out at both ends. This great corridor is called Rock House. Its existence, its location, and direction, are determined by a joint fracture which runs S. 70° W. and dips steeply to N.W. (Fig. 31). The cliff face of the projecting mass is parallel to the master joint of Rock House and apparently is located on another joint of the same system. The joint fracture cuts the floor of Rock House along the northwest side of the room and cuts the roof along the median line from end to end. The general cross-section form of Rock House is that of a Gothic arch, widest at the base and narrowing to the top into the joint fracture as shown in Figure 29. Certain less resistant beds just above the floor level have apparently caused the wider lower part.

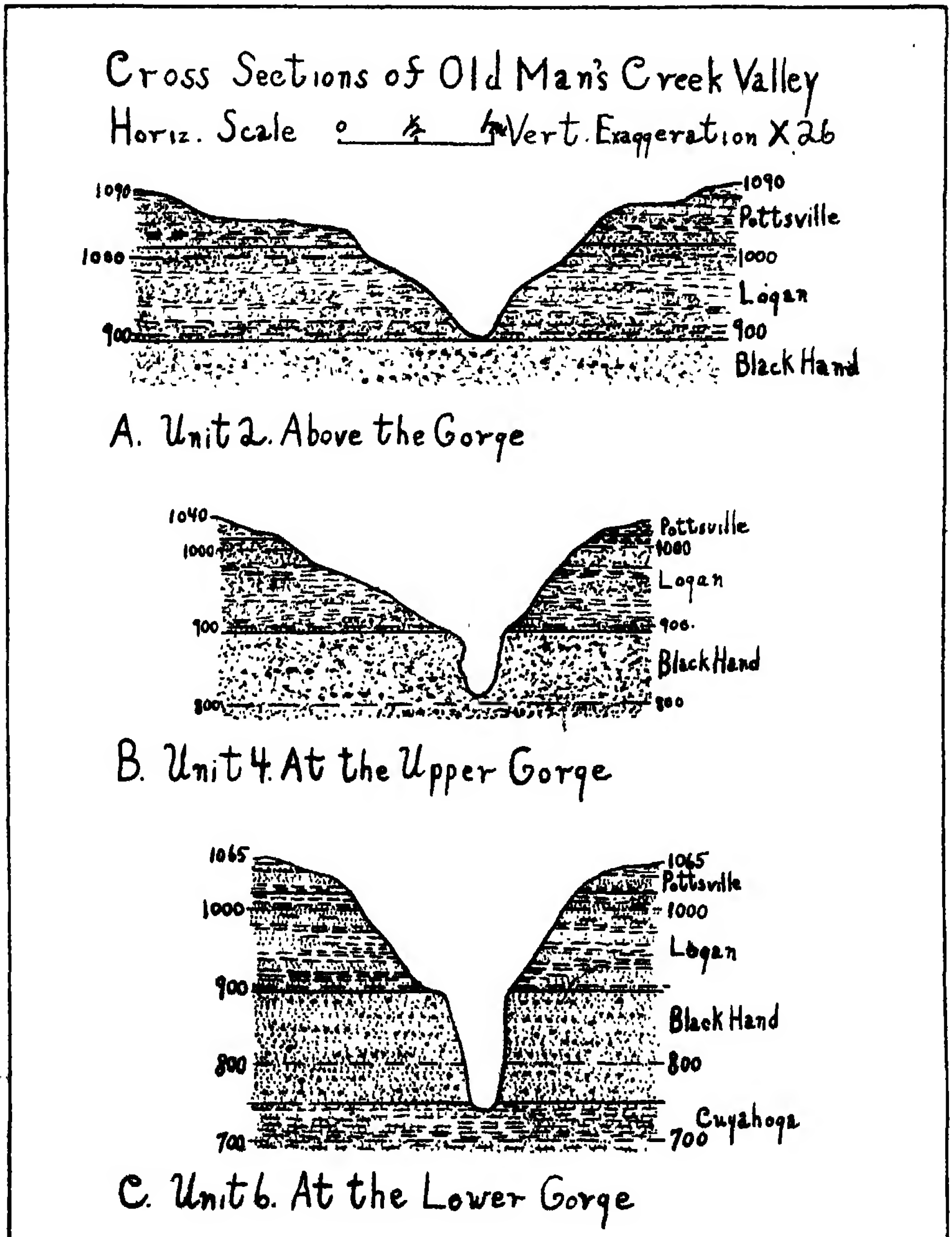


Fig. 23. Cross sections of Old Man's Creek Valley showing the relation of the form of the valley to the lithology of the rock units.

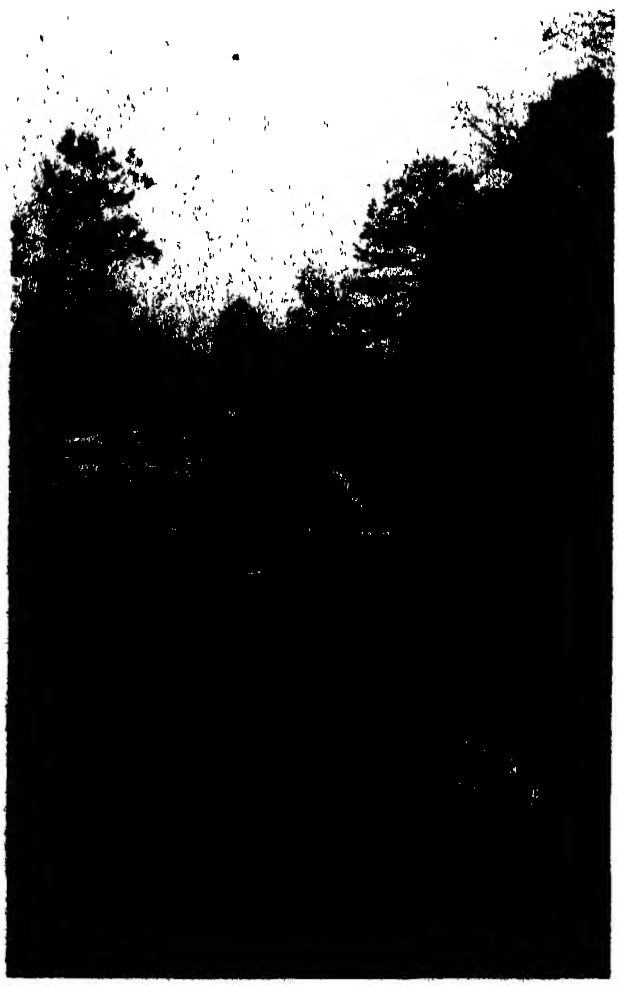


Fig. 24. Old Man's Creek showing in the background the stream spread out on the upper surface of the Black Hand sandstone and in the foreground the cascade at the head of the Upper Falls.

Fig. 25. The Upper Falls by which Old Man's Creek enters the head of the Upper Gorge. The upper part of the Black Hand sandstone is shown. (Ohio Division of Forestry. Photo by Bob Wheaton).

Fig. 26. The Lower Falls by which Old Man's Creek enters the head of the Lower Gorge. The falls is over only the lower part of the Black Hand sandstone but the entire formation is shown in the valley wall. The plunge basin is probably in the Cuyahpga shale below.

Fig. 27. Old Man's Cave looking down the valley. The sloping ceiling and the uneven weathering of the sandstone are well shown. (Ohio Division of Forestry. Photo by Bob Wheaton).

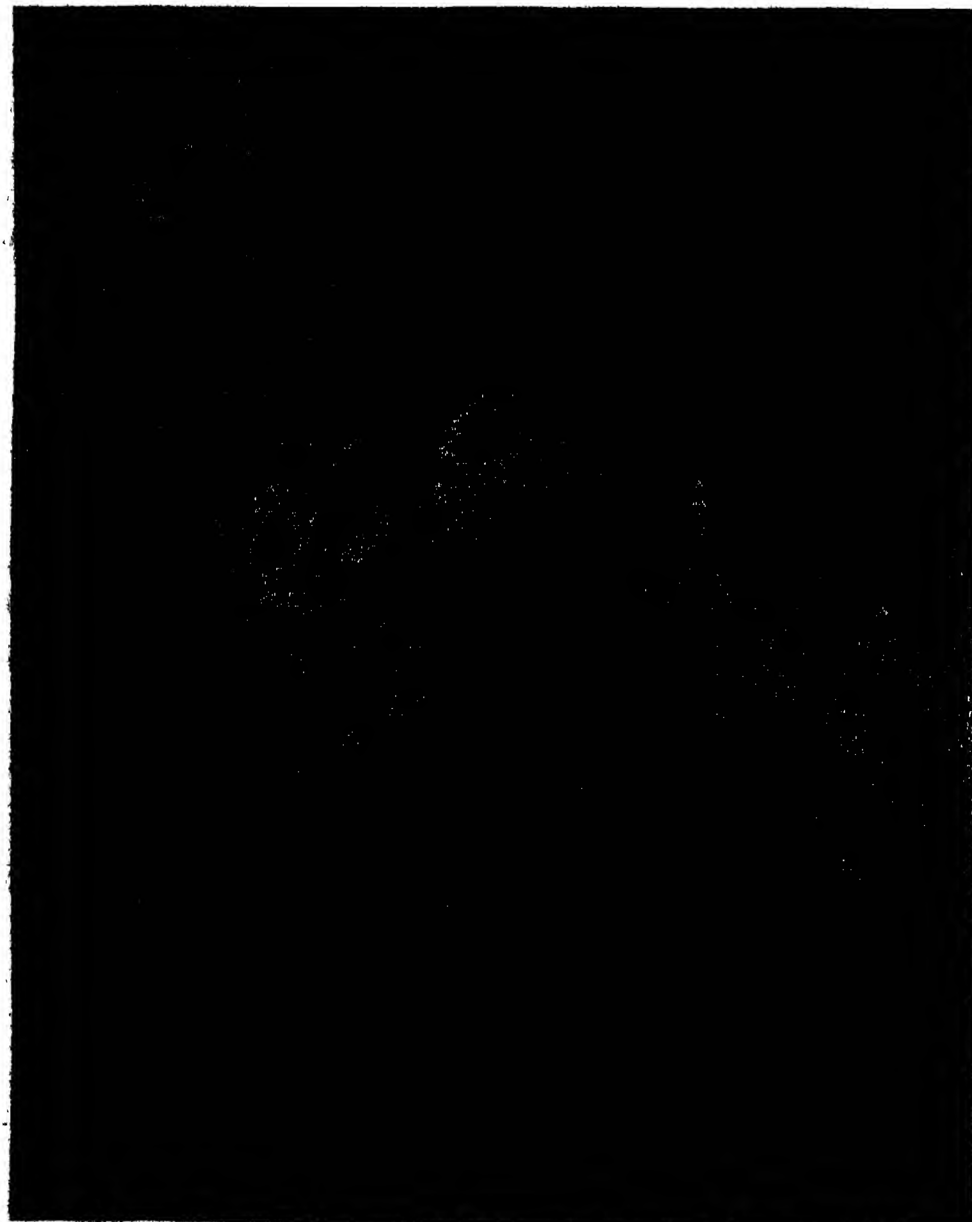


Fig. 28. The Black Hand sandstone cliff on the face of Rock House. The dark reentrants are the windows leading into Rock House. (Ohio Division of Forestry. Photo by Bob Wheaton).

Fig. 29. Looking southwest along the corridor of Rock House showing the open southwest end and the windows on the right which admit the light. (Ohio Division of Forestry. Photo by Bob Wheaton.)

Fig. 30. The opening at the southwest end of Rock House protected by a rock canopy of the firm upper beds of the Black Hand sandstone. (Geol. Surv. Ohio, Report of Progress in 1870.)

A second set of joints, somewhat unequally spaced, cuts the sandstone approximately at right angles to the cliff and to the master joint along which Rock House is developed (see Fig. 31). Weathering along these joints has made window-like openings through the outer wall of Rock House. Five such openings exist and cut the outer wall into six great pillars of quite unequal size. The line of the

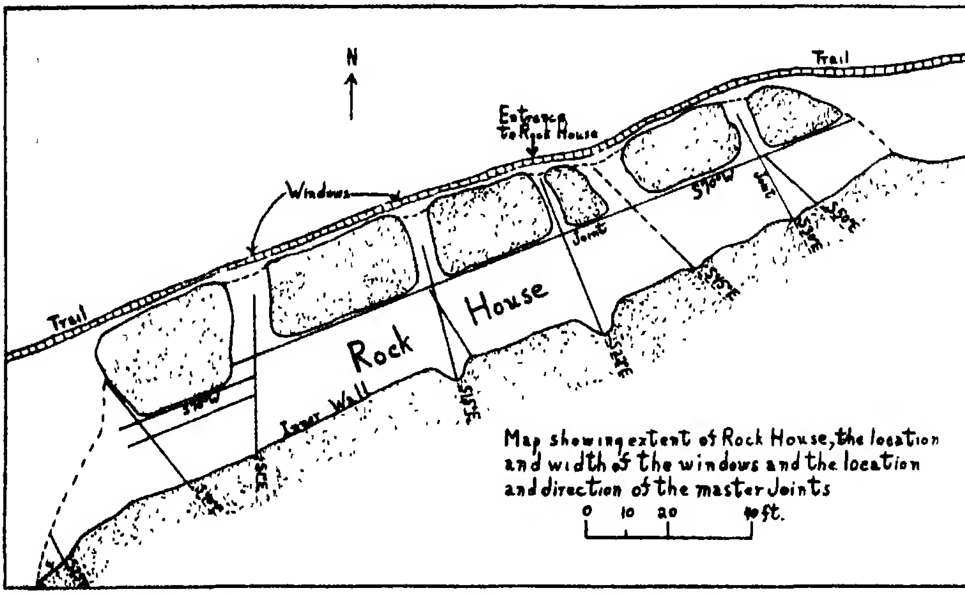


Fig. 31. Map showing the extent of Rock House, the location and width of the windows, and the location and direction of the master joints.

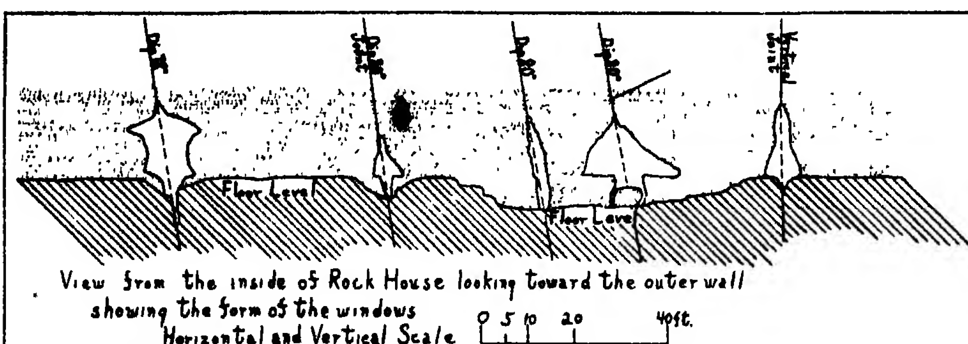


Fig. 32. View from the inside of Rock House looking toward the outer wall showing the form of the windows, and the position of the cross joints.

joint fracture that caused each opening can be traced across the roof of Rock House and down the inner wall where a weathered out niche marks the line of each joint. The window-like openings, as shown in Figure 32 also have the form of Gothic arches and the great pillars are smallest at the base and enlarge upward to compensate for the form of the window openings.

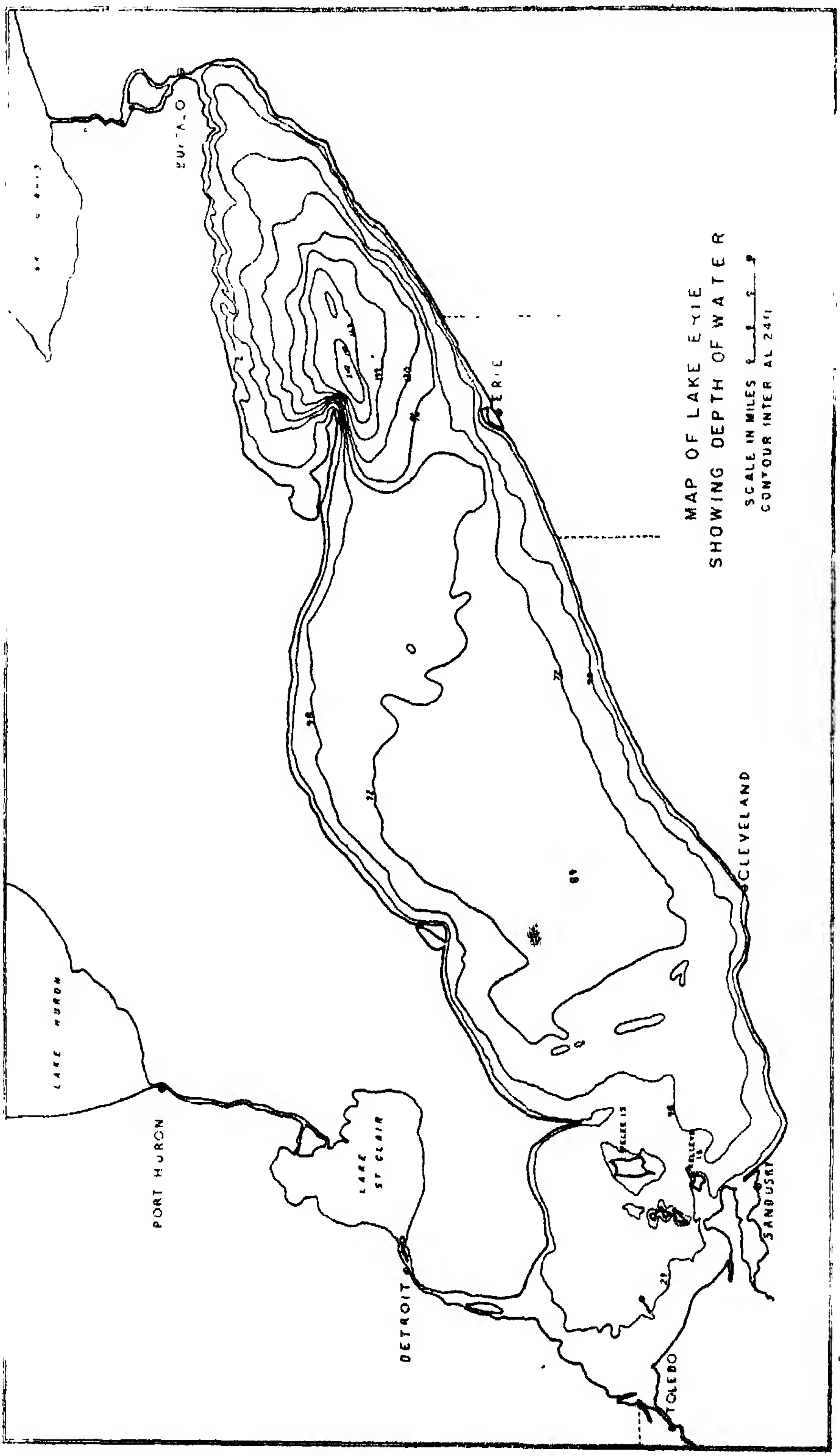


Fig. 33. Map of Lake Erie showing by contours the depth of the water, which furnishes a basis for a division into eastern, central, and western units.

The middle one of the five openings is the easy entrance to Rock House but two other openings and the northeast end can be entered by climbing. The southwest end of Rock House opens out at 30 to 40 feet above the base of the cliff as so well shown in Figure 30 reproduced here from an old sketch first published in a report of the Geological Survey of Ohio in 1870. Above this opening thick beds of the firmer upper part of the Black Hand sandstone project like a canopy above and beyond the opening. Rock House, like the several rock-shelter caves, is developed in the horizon of the cross-bedded, poorly-cemented middle part of the Black Hand sandstone.

The evidence is conclusive that the greater weathering of the sandstone along the joints has been the chief cause for the formation of Rock House. The sandstone is rather loosely cemented and the slow but persistent decay of the cement allows sand grains to fall away from ceiling and walls. It is believed this is the chief method of enlargement.

If it appears that the slow falling away of sand grains is an inadequate method for forming the great corridor of Rock House, it may be noted that if the sand necessary to fill the 100,000 cu. ft. of space in Rock House was removed during the one million years of the Pleistocene period the rate of removal would be about one-half of an ounce of sand grains per day, which does not seem an unreasonable rate. It is believed that wind is the most important and almost the sole agent for the removal of the sand grains from the floor of Rock House.

LAKE ERIE BASIN AND ISLANDS

The Lake Erie basin may be very naturally divided on the basis of depth into three parts which by location may be called the eastern, central, and western sections, as shown in Figure 33. The Eastern section east of a line from Erie, Pennsylvania, to the base of Long Point on the north shore is the deepest part with considerable area below 120 feet and a maximum depth of 210 feet. The Central section is a broad basin with a relatively even bottom and of intermediate depth largely between 60 and 75 feet, and with a maximum of 84 feet.

The Western section, west of a line from Point Pelee to Cedar Point at Sandusky is the shallowest and the smallest part with most of the floor between 25 and 35 feet and the deepest record 48 feet. In contrast with the other two sections the Western section contains a number of islands and shoals in its eastern part which partly close it off from the Central section.

A satisfactory explanation of the varying depth of the Lake Erie basin can apparently be found in the differential hardness of the bedrock and in erosion by streams and by the ice sheets. The rock strata of the Lake Erie region dip slightly to the south and the outcrop bands of the several rock units have a general east-west direction roughly paralleling Lake Erie. (Fig. 34). Lake Ontario basin, including the plain southward to the base of the Niagara escarpment is underlain by Ordovician shale. Ontario, north of Lake Erie is underlain by an east-west belt of resistant Silurian and Devonian limestone and dolomite. The basin of Lake Erie east of Sandusky is underlain by shale, shaly limestone and shaly sandstone of Upper Devonian age. Along the south border of the Lake Erie basin eastward from Cleveland there is an escarpment composed largely of Mississippian sandstone rising 200 to 300 feet above the floor of the lake basin as shown in Figure 36. This is the northwest front of the Appalachian Plateau.

The glacial ice which invaded the Lake Erie region came from the northeast over the Silurian-Devonian limestone cuesta of Ontario, and down the dip-slope into the Erie basin. Here its southward advance was obstructed by the escarpment bordering the basin on the south and the ice was directed southwestward along the line of the basin which was along the outcrop of the softer Upper Devonian shales (see Fig. 34). In the narrow eastern part of the basin these shales were eroded deeply but farther west where the angle of southward dip is less and

the width of the shale belt is greater, the glacial erosion resulted in the broader but shallower central section.

Between Cleveland and Sandusky the outcrop belt of the Devonian shales swings southward across central Ohio (Fig. 34). The shallow western section of Lake Erie is underlain by the Silurian and Devonian limestones on the northward plunging end of the *Cincinnati anticline* and on these resistant rocks the glacial erosion was slight and the western section of Lake Erie is shallow (see Figs. 34 and 33).

In the eastern part of this western section there are a number of islands as shown in Figure 35. Five of these have areas greater than one square mile and there are a dozen more of smaller extent as well as a number of shoals. The islands are arranged in two north-south belts. The western belt starts with Catawba Island, which is really a part of the mainland, and is continued north-

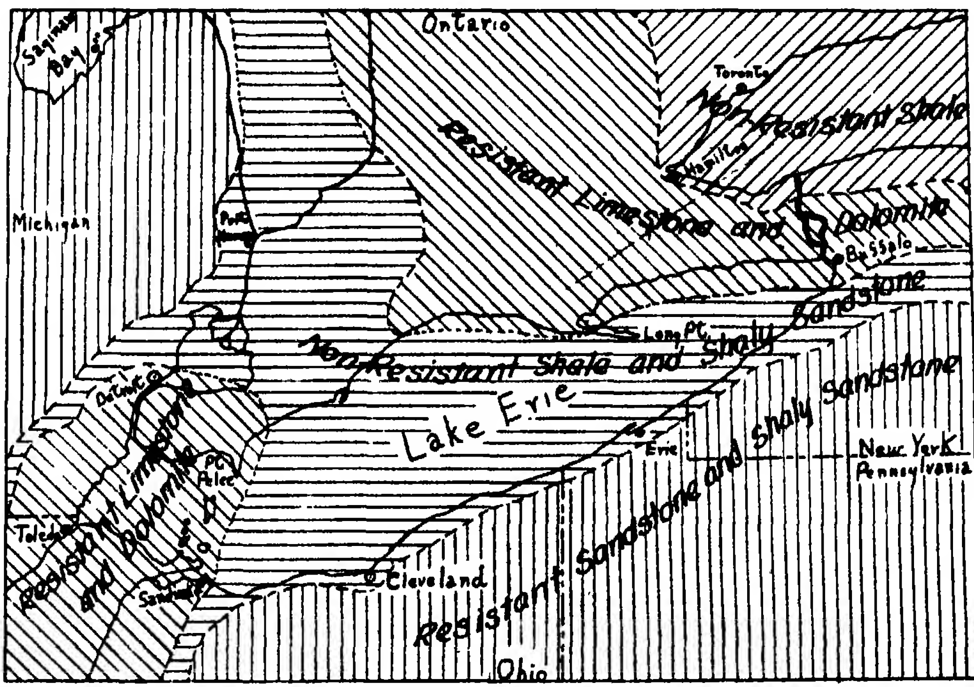


Fig. 34. Map of the Lake Erie region showing the distribution of the several rock types that have determined the relief features.

ward by the Bass Island group of three larger islands and several small nearby islands. North of the Canadian line the belt swings northwest and includes Hen Island, Big and Little Chicken Islands, East Sister, Middle Sister, and North Harbor Islands and several wave-swept reefs and shoals.

The east belt begins with the elevated east end of Marblehead peninsula and is continued northward by Kelleys Island, Middle Island just across the Canadian line, and Pelee Island the largest of the Lake Erie islands.

Some characteristics of the islands, and their relation to the lithology and structure of the bed rocks, are shown in the east-west generalized cross-section through South Bass, and Kelleys islands that forms Figure 37. This island area is on the east flank of the Cincinnati anticline and the strata dip eastward at a low angle. The rock section of the region includes the Upper Silurian Bass Island dolomites, Greenfield, Tymochtee, Put-in-Bay and Raisin River and the Devonian

units, Amherstburg and Lucas dolomites and Columbus and Delaware limestones. Both island belts are north-south cuesta ridges with steeper slopes on the west and gentler slopes to the east. The western or Bass Island ridge is formed chiefly by the very resistant Put-in-Bay dolomite. The eastern or Kelleys Island ridge is formed by the Columbus limestone.

Along the south part of the west shore of South Bass Island and the northwest shore of Catawba Islands there are bold rocky cliffs 30 to 40 feet high formed of the massive brecciated Put-in-Bay dolomite as shown in Figure 38. Such rugged

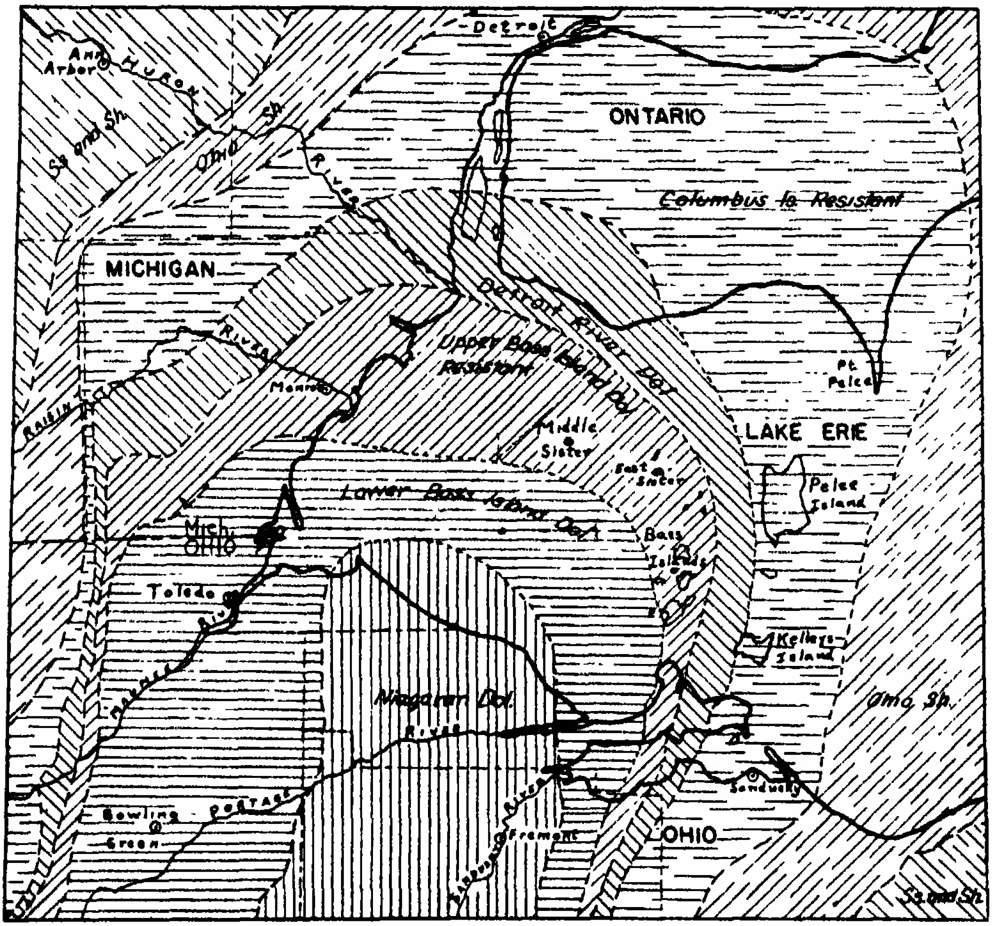


Fig. 35. Geologic map of the region around the west end of Lake Erie showing the relation of the island belts to the lithology and relative resistance of the rock units.

features are unusual for western Lake Erie or western Ohio. The lake level here is in the upper part of the next lower unit, the Tymochtee member, a soft, shaly, thin-bedded dolomite. This is eroded readily by the waves and the massive stone above is undermined and falls away in great blocks. The bed of the lake for some miles to the west is underlain by the Tymochtee shaly dolomite (see Fig. 37). Both South Bass and Catawba islands have their greatest elevations near the west shore and a general slope toward the east. This is the dip-slope of the cuesta on the bedrock surface which at places passes gradually beneath the lake surface.

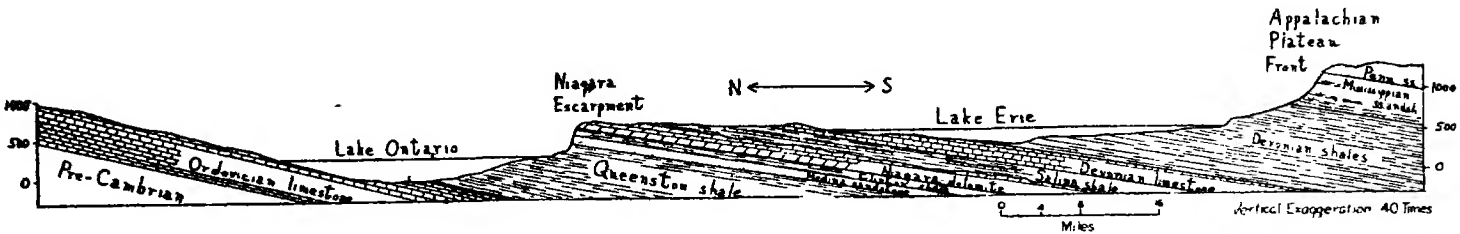


Fig. 36. North-south section across the Ontario and Erie basins and the adjoining uplands showing the relations of the basins and uplands to the lithology of the rock units.

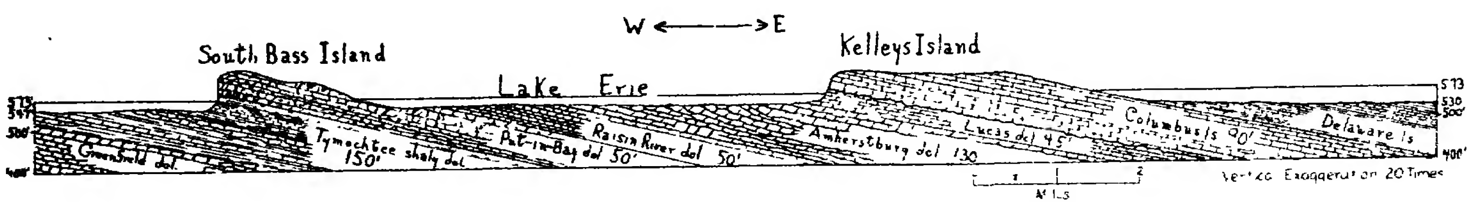


Fig. 37. East-west section through South Bass and Kelleys islands showing the cuesta form of the islands, the rock units, and the rock structure.

Although less high and less rugged, Kelleys Island on the eastern ridge also shows the cuesta form (Fig. 37). The highest elevation of the island is in the western part, and around the west shore there is generally a cliff 10 to 20 feet high the upper part of which is Columbus limestone while the lower part, at water level, is the somewhat thinner-bedded Lucas dolomite. On the east side of the island the surface slopes evenly and gently eastward toward the lake and along the shore there are large bedrock, dip-slope areas, in part glacially smoothed and striated, which pass without interruption or change beneath the lake surface.

On the floor of the channel between the two ridges the Raisin River, Amherstburg and Lucas dolomites must outcrop (see Fig. 37). As exposed on Marblehead peninsula on the south shore of Lake Erie and also along Detroit River to the north these units have a combined thickness of 150 to 200 feet. They are less resistant than the Put-in-Bay and the Columbus, and therefore form the low channel between the ridges.

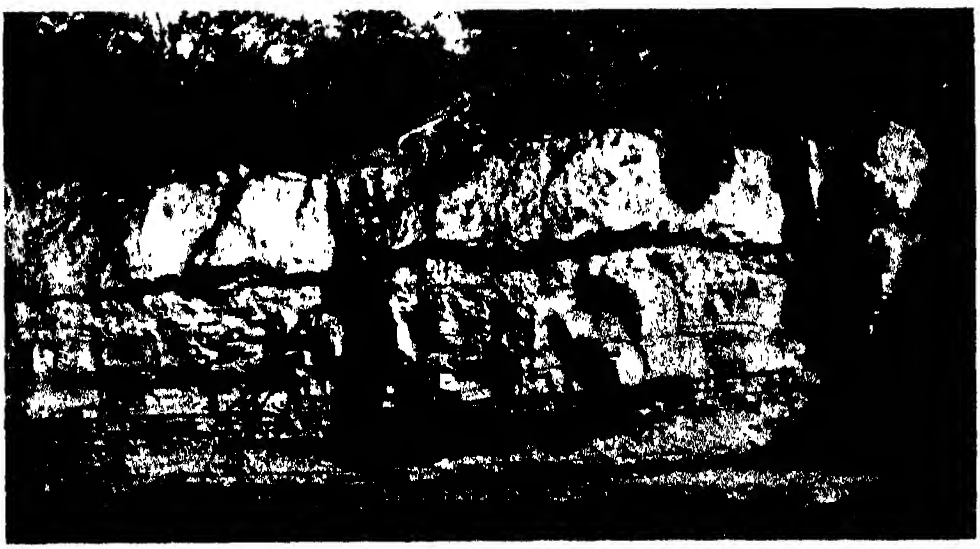


Fig. 38. Cliff along the south part of the west shore of South Bass Island. The massive brecciated Put-in-Bay dolomite which forms the cliff is being undercut near lake bed in the Tymochtee shaly dolomite.

The swing of the Cuesta ridge to the northwest is due to the swing of the outcrop belt around the end of the northward plunging Cincinnati anticline (see Fig. 35). The Put-in-Bay-Raisin River outcrop belt swings west to appear on the Michigan shore in the vicinity of Monroe and thence runs southwest across southern Monroe County and south across western Lucas County on the west side of the anticline. The Columbus limestone belt of outcrop which runs north from Pelee Island to the Ontario peninsula likewise swings westward around the end of the anticline into Michigan near Detroit and thence southwest and south on the west side of the anticline.

In conclusion may I express the hope that this little excursion into the field of geology, in which we have tried to point out the genetic relations of relief features to rock materials and the work of the common geologic agents, may in some measure increase your appreciation of scenic features, and also leave with you the realization that most of the surface features which surround us are the result of the work of common geologic agents working slowly but relentlessly through long intervals of geologic time.

TACHYURA BARNESI N. SP. (BEMBIDIINI, CARABIDAE, COLEOPTERA)[1]

WM. C. STEHR,
Ohio University, Athens, Ohio

Tachyura barnesi n. sp.
(Bembidiini, Carabidae, Coleoptera)

From robust and moderately convex. Color dark ferrugineous, shining; slightly paler along the outer margin of the elytra. Head slightly elongate, three-fourths width of the thorax at apex; eyes large, evenly convex; antennae about one-half the length of the body, pale fuscous at the apex, gradually testaceous toward the base with the first three joints clear testaceous and of equal length; palpi testaceous. The mentum with two rather deep concavities, open behind and deeper than in other species of the genus except *T. frontalis* (Hayw.). The prothorax one-third wider than long; one-third wider at the base than at the apex; apex slightly emarginate; anterior transverse impression faint but distinguishable; posterior transverse impression deep and distinct, finely punctate and with three large punctures at the middle; median line faint except near the anterior impression, abbreviated at both ends; basal impressions short and deep; basal margin straight from posterior angles to inner edge of basal impressions but perceptibly arcuate outward between the impressions; side margins of prothorax strongly arcuate anteriorly and depressed near the anterior angles, oblique posteriorly toward the posterior angles and very shallowly sinuate just anterior to them; hind angles rectangular, with a distinct low carina as long as the basal impressions and very close to the side margin. Elytra one-half wider than the prothorax, oval, moderately convex, with a sutural and four abbreviated dorsal striae, the fourth very faint; the sutural and first three dorsal striae punctate to behind the middle, the fourth dorsal apparent as a row of faint punctures on the middle third of the elytra; first dorsal setigerous puncture about one-third from the base of the elytra and the second at three-fifths. Body beneath ferruginous; legs testaceous, very slender; length 3.2 mm.

The rather distinctly punctate striae of the elytra separate the present species readily from related species except *T. ferrugineus* (Dej.) and possibly some large specimens of *T. tripunctatus* (Say) which sometimes show faintly punctured striae. From *T. ferrugineus* (Dej.) it is readily separated by the number of elytral striae and the dorsal punctures of the elytra which are at one-fourth from the base and just behind the middle in that species. From large specimens of *T. tripunctatus* (Say) it is separated principally by the much more distinctly punctured striae of the elytra, the paler elytral margin, its greater convexity, deeper basal impressions of the thorax, more distinct carinae of the basal angles of the thorax, arcuate median portion of the base of the prothorax and deeper foveae of the mentum.

Holotype Female.—Collected on a gravel bar along the Muskingum River in Muskingum Township, Washington County, Ohio, July 14, 1939, by Mr. Ralph C. Barnes who kindly donated the type to the author.

BIBLIOGRAPHY

Casey, Thomas L. 1918. Bembidiinae, pp. 1–223, Memoirs on the Coleoptera, Vol. VIII. Lancaster, Pa.

Hayward, Roland. 1899. A study of the species of *Tachys* of Boreal America. Trans. Am. Ent. Soc., XXVI: 191–238.

[1]Paper No. 28, from the Department of Zoology, Ohio University, Athens, Ohio.

ANNUAL REPORT OF THE OHIO ACADEMY OF SCIENCE 1946

THE OHIO ACADEMY OF SCIENCE

Organized 1891 — Incorporated 1892

Affiliated with the American Association for the Advancement of Science

OFFICERS AND COMMITTEES FOR 1946–1947

President

H. H. M. Bowman

Vice-Presidents

A. *Zoology:* William C. Beaver
B. *Plant Science:* C. J. Willard
C. *Geology:* K. C. Cottingham
D. *Medical Sciences:* Normand Hoerr
E. *Psychology:* Herbert A. Toops
F. *Physics and Astronomy:* Harold P. Knauss
G. *Geography:* Alfred J. Wright
H. *Chemistry:* Ralph V. Sinnett
I. *Mathematics:* (Not elected).
J. *Junior Academy:* (Not elected)
K. *Anthropology:* F. G. Detweiler

Secretary

Rush Elliott

Treasurer

Wilbur M. Tidd

Historian

William H. Alexander

Executive Committee

Ex-Officio: H. H. M. Bowman, Rush Elliott, and Wilbur M. Tidd

Elective: J. E. Carman and A. W. Lindsey

Trustees of the Research Fund

M. E. Stickney, term expires	1947
J. Ernest Carman, term expires	1948
Herbert Osborn, *Chairman*, term expires	1949

Library Committee

Mrs. Ethel M. Miller, *Chairman*

Librarian in charge of Academy Exchanges and Publications

William Lloyd Evans, term expires	1947
A. C. Anderson, term expires	1948

Committee on Conservation

Roscoe W. Franks, term expires	1947
T. H. Langlois, *Chairman*, term expires	1947
E. L. Wickliff, term expires	1947
G. W. Conrey, term expires	1948
C. L. Dow, term expires	1948
E. W. E. Schear, term expires	1948
Arthur Harper, term expires	1949
George W. White, term expires	1949
C. E. Taft, term expires	1949

Committee on Nominations for 1946–1947

The Vice-Presidents of 1945–1946—George W. White, *Chairman*

Membership Committee for 1946–1947

A. *Zoology:* RALPH W. DEXTER
B. *Plant Science:* J. ARTHUR HERRICK
C. *Geology:* J. J. WOLFORD
D. *Medical Sciences:* CLINTON M. OSBORN
E. *Psychology:* JAMES VAUGHN
F. *Physics and Astronomy:* (Not elected)
G. *Geography:* FRANK J. WRIGHT
H. *Chemistry:* W. M. BURGESS
I. *Mathematics:* (Not elected)
J. *Junior Academy:* (Not elected)
K. *Anthropology:* JOHN W. BENNETT

Academy Representatives

1. On the Joint Administrative Board of the Ohio Journal of Science:
   WILLIAM LLOYD EVANS, term expires ..1947
   A. C. ANDERSON, term expires. 1948
2. On the Council of the A. A. A. S.: RUSH ELLIOTT
3. On the Save-Outdoor-Ohio Council: ROSCOE W. FRANKS.

The Council for 1946–1947

ANDERSON, A. C.
BEAVER, WILLIAM C.
BENNETT, JOHN W.
BLAYDES, GLENN W.
BOWMAN, H. H. M.
BURGESS, W. M.
CARMAN, J. ERNEST
COTTINGHAM, K. C.
DETWEILER, F. G.
DEXTER, RALPH V.
ELLIOTT, RUSH
EVANS, WILLIAM LLOYD
HERRICK, J. ARTHUR
HOERR, NORMAND
KNAUSS, HAROLD P.
LANGLOIS, T. H.
LINDSEY, A. W.
MILLER, MRS. ETHEL M.
MILLER, JOHN A.
'OSBORN, HERBERT
OSBORN, CLINTON M.
SHETRONE, H. C.
SINNETT, RALPH V.
TIDD, WILBUR M.
TOOPS, HERBERT A
VAUGHN, JAMES
WILLARD, C. J.
WOLFORD, J J.
WRIGHT, ALFRED J
WRIGHT, FRANK J

REPORT OF THE FIFTY-FIFTH ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE

After skipping one year, due to government restrictions on public meetings, the Academy was able to resume its annual meetings in 1946 on the campus of The Ohio State University, May 2, 3, and 4. With the exception of sections I and J, every section presented a program, their length varying from a half-day to three times as much. Judging by reports which reached the secretary from several Vice-Presidents attendance was generally far above expectations. A few more than one hundred titles of papers read at the sectional programs, most of them listed in the printed program, still further testify to the success of this meeting. The address of the retiring President, Dr. J. Ernest Carman, on the Geologic Interpretation of Scenic Features of Ohio, was another exceptional feature of the meeting. It was a very lucid and interesting explanation of some of the outstanding features of our beautiful state which combined general interest with scientific interpretation.

The meeting included no general public programs. It opened as usual with the annual meeting of the Council, which took place at 8:00 P. M., May 2. Sectional meetings occupied Friday and Saturday.

The banquet was served in the Faculty Club with Dr. John W. Price, Chairman of the Local Committee on Arrangements, as an able toastmaster. Vice-President Bland L. Stradley of the Ohio State University, welcomed the group, and Dr. Frank J. Wright of Denison University responded for the Academy. This part of the program concluded with President Carman's retiring address.

In the annual business meeting, due to wartime inactivity of the Academy, only a few routine matters were presented. Those of general interest were the election of officers, whose names appear in the preceding pages, and the presentation of the following names of fellows, newly elected by the Council:

John William Bennett	Jack Sargent Harris	James Franklin Pepper
Ralph J. Bernhagen	James G. Haub	Gordon Rittenhouse
Aureal Theophilus Cross	Zeph J. R. Hollenbeck	William Henry Sassaman
Henry Frederick Donner	Lincoln La Paz	Paul R. Shaffer
David Hosbrook Dunkle	John Robert Lockett	Jacob Jonathan Schmidt
Edna E. Eisen	Robert Hamilton Mitchell	

With the brief report of Dr. E. M. Spieker for the Committee on Resolutions, thanking our hosts for their contribution to the success of the meeting, the group adjourned.

Respectfully submitted,

A. W. Lindsey, *Secretary*

REPORT OF THE EXECUTIVE COMMITTEE AND COUNCIL

Owing to the inactivity of the Academy during the past year the Executive Committee met only once, on February 22, 1946, to consider plans for the Annual Meeting. Only a few suggestions for a meeting place had been received and no actual invitations, hence the Committee concluded that it would be wise to meet at Columbus, partly to minimize travel and the need for hotel accommodations. Through the willingness of our members on the Ohio State University faculty this plan was carried out, with May 2, 3 and 4 as the dates for the meeting.

The Committee also considered the reinvestment of $1300.00 received from called securities and authorized the Treasurer, Dr. C. E. Taft, to invest the sum in Government G Bonds.

It was thought useless to call a meeting of the entire Council prior to the Annual Meeting, hence this body also met but once, on May 2, 1946.

The meeting was called to order by President J. Ernest Carman with twenty-one members in attendance.

The meeting was occupied largely with reports of committees which are published in detail herewith. One only is excepted. This report, presented by Dr. T. H. Langlois for the Committee on Conservation, made several recommendations relating to the natural resources of Ohio which would involve legislation. On motion of Dr. John A. Miller, seconded by Dr C. J. Willard, the report was accepted and its suggestions were opened for discussion. One, providing for the issuing of permits to competent scientists for collecting for scientific purposes animals protected by laws was unanimously approved by the Council on motion of Dr F. H. Krecker, seconded by Dr. Langlois. The Secretary was instructed to transmit copies of this recommendation to the Conservation Commission, the Conservation Committees of the House and Senate, and Mr. Roscoe W. Franks.

In discussion of the remaining suggestion the Secretary spoke on the activities of the Academy Conference of the A. A. A. S. recommending greater co-operation of state academies in the practical work of conservation and moved that the President appoint a committee of three, including members most familiar with legislative procedure, to consider these and other significant matters involving legislation. The motion was seconded by Dr. W. B. Steidtmann. Dr. Krecker moved to amend by asking the committee to make recommendations to the Council at its next meeting. Dr. Glenn W. Blaydes seconded the amendment, which was passed. The amended motion was then passed by a majority vote. The report of the Conservation Committee is therefore being withheld from publication at this time, pending action by the newly authorized committee.

Dr. C. J. Willard reported for the Membership Committee a list of forty-three applications for membership, an exceptionally large number. These applications were duly accepted.

President Carman announced the appointment of a committee on the Junior Academy, authorized at the last meeting of the Council. The appointees are Dr. C. H. Bennett, Dr. Arthur Harper and Dr. F. H. Krecker, Chairman.

Another item mentioned at the meeting which the Secretary believes to have been omitted from the last published report was the gift last year of $100.00 to the research fund by Dr. Herbert Osborn. The Council had previously voted its thanks to Dr. Osborn for this generous gift.

The Secretary presented nominations for fellowship and the nominees, whose names are listed in the report of the Annual Meeting, were unanimously elected as Fellows of the Academy.

Dr. Paul Rothemund spoke on the formation of an Ohio Chemists' Committee on Professional Practice and the possibility of Section H becoming associated with it.

The meeting then adjourned.

Respectfully submitted,

A. W. LINDSEY, *Secretary.*

REPORT OF THE TREASURER

COLUMBUS, OHIO, August 15, 1946.

To the Ohio Academy of Science:

I submit herewith a financial statement of the condition of the Ohio Academy of Science as of December 31, 1945. The books have been audited and the opinion of the auditor is herewith attached.

Respectfully submitted,

CLARENCE E. TAFT, *Treasurer.*

OHIO ACADEMY OF SCIENCE BALANCE SHEET AS AT DECEMBER 31, 1945

ASSETS

CURRENT EXPENSE FUND:			
Cash in Bank			$2,323.31
Bonds Owned: War Savings Series F (Cost)			111.00
Dues Receivable			112.50
Total Assets—Current Expense Fund			$2,546.81
RESEARCH FUND:			
Cash in Bank		$ 335.01	
Stocks Owned: Banc-Ohio Securities Stock (Cost)		437.50	
Bonds Owned: Fort Hayes Hotel, Columbus, Ohio (Cost)	$1,300.00		
War Savings—Series G (Cost)	100.00		
Total Bonds Owned		$1,400.00	
Total Assets—Research Fund			2,172.51
TOTAL ASSETS			$4,719.32

LIABILITIES AND NET WORTH

CURRENT EXPENSE FUND:		
Liabilities: Accounts Payable		$ 207.90
Deferred Credits:		
1946 Dues Collected in 1945	$ 17.50	
Reserve for Uncollected Dues	112.50	
Total Deferred Credits		130.00
Total Liabilities and Deferred Credits		$ 337.90
NET WORTH:		
Ohio Academy of Science:		
Current Expense Fund	$2,208.91	
Research Fund	2,172.51	
Total Net Worth		4,381.42
TOTAL LIABILITIES AND NET WORTH		$4,719.32

Ohio Academy of Science Statement of Income and Expense
For the Year Ended December 31, 1945

Current Expense Fund

Income:		
Dues from membership: Regular		$1,277.50
Life Memberships		25.00
Total Dues from Membership		$1,302.50
Grants for Research		100.00
Sales of Publications		37.12
Interest on Bonds		19.50
Total Income		$1,459.12
Operating Expenses:		
Subscriptions—Ohio Journal of Science	$ 763.50	
Printing—Proceedings of Ohio Journal of Science	177 90	
Research Grants	100.00	
Postage	15.00	
Office Supplies and Expense	7.06	
Clerical Expense	11.75	
Secretary's Honorarium	100.00	
Auditing Expense	15 00	
Bond of the Treasurer	5.00	
Safety Deposit Box Rent	3.60	
Miscellaneous	10 00	
Total Operating Expenses		1,208.81
Excess of Income over Expense		$ 250.31

Ohio Academy of Science Schedules
For the Year Ended December 31, 1945

1. Dues for Year:		
1945:		
Paid in 1944		$ 15 00
Collected in 1945: Regular	$1,192 50	
New Members	32 50	
		1,225 00
Total 1945 Dues		$1,240 00
1944 Dues Paid in 1945		35 00
1943 Dues Paid in 1945		2 50
Total Current Dues Collected		$1,277.50
1946 Dues Collected in 1945		17.50
Total Dues Collected		$1,295 00
2. *Dues Receivable:		
1945 Unpaid Dues		$ 97.50
1944 Unpaid Dues		10.00
1943 Unpaid Dues		2.50
1942 Unpaid Dues		2.50
Total Dues Receivable		$ 112.50

*This does not include amounts due from members who have been dropped because of non-payment of dues.

AUDITOR'S CERTIFICATE

COLUMBUS, OHIO, July 1, 1946.

The Ohio Academy of Science,
Columbus, Ohio.

GENTLEMEN:

In accordance with your instructions, I have examined the accounts and records of the Ohio Academy of Science for the year ended December 31, 1945.

I have also examined the accounts and records of the Ohio Academy of Science for the period January 1, 1946, to April 30, 1946. The records of Dr. Taft were in good order and all assets were accounted for as at the date he turned the records over to the new Treasurer Dr. Tidd.

I hereby certify that in my opinion, the books and records kept on a cash basis are in accordance with accepted accounting principles.

In my opinion, the accompanying Balance Sheet and Statement of Income and Expense for the Current Expense Fund fairly presents the financial condition of the Ohio Academy of Science as at December 31, 1945, and the results of operations for the year ended at that date.

Respectfully yours,
D. M. SHONTING, *Certified Public Accountant*

REPORT OF TRUSTEES OF THE RESEARCH FUND

For the year 1945 grants were made to Dr. J. N. Wolfe for continuation of his ecological studies in the Hocking Valley and to Mr. C. H. Sturgeon of the State Normal College at Ypsilanti, Mich., for a study of the stratigraphy, petrology and paleontology of the Salem limestone in eastern Ohio, sponsored by the geological department of Ohio State University.

These grants were covered by the allowance from the A. A. A. S. and there is a balance of available funds in the Academy treasury which with the expected allowance for 1946 from the A. A. A. S. will make it possible to give two or more modest grants during the current year. So far no requests have been received and your trustees would be pleased to have members bear this in mind when they learn of any project which can be helped by such a grant as the Academy can make.

With returning conditions for normal research activity there must certainly be many projects which can be assisted in this way.

Respectfully submitted,
(Signed Trustees), F. C. BLAKE,
M. E. STICKNEY,
HERBERT OSBORN, *Chairman.*

REPORT OF THE LIBRARY COMMITTEE

COLUMBUS, OHIO, May 2, 1946.

To the Council of the Ohio Academy of Science:

The sales of publications for 1945 including sales tax, amounted to $41.83. This was the largest sum since 1935 when the amount was $50.05. Twenty-five Special Papers were sold to thirteen individuals in addition to a nearly complete set of the Academy Proceedings which was purchased by a western college. As usual Dr. W. G. Stover's Agaricaceae paper headed the list with twice as many copies as the next highest.

In 1942 it was reported to the Council that all the foreign exchanges outside the Americas had been removed early in 1941 from the mailing list of the Ohio Journal of Science except fourteen which had assumed the risk of transportation. In May, 1942, all the foreign addresses were removed, although the Canadian ones were soon replaced. The stock of each issue of the Journal has been stored in the Botany and Zoology library to be posted at the end of the war to the institutions still in existence.

The addresses are now being replaced just as fast as mail service for periodicals is resumed with the various countries. Last July 151 names in 35 countries were replaced and all back volumes were posted to 132 of them for 19 were still limited to 1-lb. parcels and the back volumes weighed over eight pounds. It required 20 parcels and the postage was $106.00. This was paid by the Journal management for it would have done so if the issues had been mailed at the regular time of publication. So far this year 45 more names in 13 countries have been put back onto the mailing list for Volume 46 and the back volumes are now being assembled and packed for the 64 addresses. Only a few countries remain off the list and they will be replaced as soon as mail service is resumed. The Journal management will continue to pay the postage on the back volumes.

On the other hand back volumes are arriving almost constantly from the foreign exchanges to complete our sets of their publications. Thus it may not be so long until the exchange situation is nearly back to normal and only the current issues will be sent and received.

Several new exchanges have been added and some of the older ones have begun to publish new journals which are being sent in addition to those which they were already sending to us.

As would be expected it has been necessary to make more changes than usual in the mailing list for the addresses of the members of the Academy.

Respectfully submitted,

WILLIAM LLOYD EVANS,
A. C. ANDERSON,
ETHEL MELSHEIMER MILLER, *Chairman.*

OHIO ACADEMY OF SCIENCE SALES
January 1—December 31, 1945

		PRICE	TAX
Jan. 9.	C. M. Finfrock, Western Res. Univ., Sp. P. 20, 3 Cop.	$1.50	
Jan. 23.	G. H. Beatty III, Merion, Pa., Sp. P. 2, 5, 8	1 60	
Feb. 14.	Robert Teeters, Philadelphia, Sp. P. 1, 7, 9, 12.	2 10	
Mar 27.	P. Hale, Botany Dept., O. S. U., Columbus, Sp. P. 18.	.75	.03
April 20.	H. F. Hansell, Middletown, Sp P. 3	.50	.02
April 26.	P. Hale, Botany Dept., O. S. U., Columbus, Sp. P. 16	.50	.02
April 27.	F. G. Dickason, Wooster, Sp. P. 18.	.75	03
April 28.	T. A. Koshy, Allahabad, India, Sp. P. 18	.75	
June 16.	C. L. Worley, Hiram, Sp. P. 11, 16....	1 00	03
June 22.	Mrs. Lida Whittier, Cleveland, Sp. P. 18	.75	.03
Aug. 6.	Oregon State College Library, Corvallis, nearly complete set	24 30	
Oct. 3.	A. F. Beyer, Univ. Cincinnati, Sp. P. 18, 5 cop	3.75	
Oct. 4.	A. B. Williams, Cleveland Mus. Nat. Hist., Sp. P. 11..	.50	
Oct. 26.	A. F. Beyer, Univ. Cincinnati, Sp. P. 18..	.75	
Dec. 11.	Mrs. H. M. Spandau, Lexington, Sp. P. 2, 5, 16.	1.00	05
Dec. 26.	R. B. Rypma, Athens, Sp. P. 3 ..	.50	.02
	Total..	$41.60	.23

FINANCIAL STATEMENT OF SALES

Sales for 1945....	$41.60
Sales Tax receipts	.23
	$41.83

EXPENDITURES

Feb. 26, 1945, paid on 1945 sales	$ .21
June 26, 1945...	8.72
Oct. 27, 1945...	24.30
Dec. 31, 1945	.50
Feb. 23, 1946....	1.60
March 27, 1946....	1.09
May 1, 1946....	4.92
July 10, 1945, 50 1-cent sales tax stamps...	.49
Total..	$41.83

REPORT OF THE JOINT ADMINISTRATIVE BOARD OF THE OHIO JOURNAL OF SCIENCE

COLUMBUS, OHIO, April 25, 1946.

To the Ohio Academy of Science:

The annual meeting of the Joint Administrative Board of the Ohio Journal of Science was held at Columbus, Ohio, April 25, 1946. The meeting was called to order by Chairman Snyder. Present were Drs. Snyder and White representing the Ohio State University, Drs. Evans and Anderson representing the Ohio Academy of Science and Drs. Blaydes and Miller representing the Ohio Journal of Science.

The minutes of the preceding meeting were read and approved.

Upon a motion by Dr. Anderson which was seconded by Dr. Evans, Drs. Blaydes and Miller were unanimously elected Editor and Business Manager respectively, for the year 1946–47.

Drs. Snyder and White were appointed by the board to audit the accounts of the Journal for the year 1946–47.

Dr. Blaydes was called upon for the editor's report, a copy of which is herewith attached. A review of the papers presented in Volume 45, together with a discussion pertaining to extending the range of areas included, followed.

Dr. Evans moved that the chairman of the board and the editor constitute a committee to fill a vacancy on the editorial staff which was created by the resignation of Dr. Jarvis, was seconded by Dr. White. Motion passed.

It was further agreed that Dr. Blaydes be authorized to accept upon his discretion such papers as may be presented during the symposium conducted by the Medical Section of the Academy and publish the same in the Journal, provided, that the Journal receive from the Medical School or its agent the sum of $250.00 to aid in the publication of the same.

Dr. White moved that the editor be given permission to experiment with the publication of short notes for the period of one year and to report at the next annual meeting of the board upon the results. This motion was seconded by Dr. Anderson and passed by the board.

Dr. Evans moved that the report of the editor be accepted This motion was seconded by Dr. White and passed by the board.

The Chairman next called for a report from the Business Manager. Dr. Miller's report was in the form of a financial statement for Volume 45 of the Ohio Journal of Science, a copy of which is herewith attached. Dr. Miller directed the attention of the board to several pertinent facts relative to continued increases in cost of publication. He cited the fact that this year's budget was the largest in the history of the Journal.

It should be noted that the Journal is now receiving $1,000.00 as a contribution from The Ohio State University. The Academy, on the other hand, contributed $774.00 for the fiscal year.

The business manager announced the receipt of a gift of $500.00 from Dr. C. F. Kettering. This benevolent act was made possible largely through the efforts of Dr. P. Rothemund. The business manager expressed his desire that this gift and the loyal support of Dr. Rothemund be called to the attention of the Academy.

A review of the balance sheet will disclose the prediction made one year ago to the Academy, that, namely the income from the University and the Academy, together with subscriptions, etc., are insufficient to defray the current costs of publication. Were it not for the gift from Dr. Kettering and the payment by the Academy of the 1944 proceedings the Journal would today be in debt. It was strongly urged that the Academy match the University in supporting the Journal.

Dr. Evans moved the acceptance of the report of the Business Manager, seconded by Dr. White and passed by the board.

There being no further business to come before the board it was adjourned.

Respectfully submitted,

JOHN A. MILLER,
Secretary of the Board.

The Editor's Report to the Joint Administrative Board of the Ohio Journal of Science
April 25, 1946

The Ohio Journal of Science, Vol. 45, 1945:

Total number of pages printed in Vol. 45		306
* Number of papers in Vol. 45		28
Distribution of papers by subject:		
Botany	7	
Chemistry	2	
Climate (weather)	1	
Entomology	5	
Genetics	2	
Geology	3	
Ohio Acad. Annual Report, including Constitution and By-Laws and Membership List	1	
Zoology	7	
Total	28 papers	
Book Reviews	9	

Review Papers:
Fueling a Global War, Max W. Ball, Jan., 1945.
Problems of Suflonamide Chemotherapy, May, 1945.

Financial Report of The Ohio Journal of Science—Fiscal Year 1945

RECEIPTS

Balance from 1944	$ 127.69
University Allowance	1,000.00
Ohio Academy of Science—pro rata of dues	763.50
Ohio Academy of Science—pro rata of dues	10 50
Ohio Academy of Science—Proceedings 1944	195.29
Ohio Academy of Science—Proceedings 1945	167 40
Subscriptions	102 00
Sale of Back Numbers	98 95
Author's Payment for Plates	129 03
Special Grant from the University Graduate School	215 00
Gift from C. F. Kettering	500.00
Total Receipts	$3,309.36
Check outstanding (No. 440, Postmaster)	34.90
	$3,344.26

EXPENDITURES

Spahr and Glenn, Printing—Volume 45	$2,022.24
Bucher Engraving Company	561.14
Postmaster—Mailing current number	80.75
Postmaster—Foreign mailing cost	106.00
Bank Charges	2.73
Clerical Assistance	26.50
Columbus Blank Book Company—Supplies	5.82
	$2,805.18
Balance on hand, February 23, 1946 (Huntington National Bank)	539.08
	$3,344.26

REPORT OF THE COMMITTEE ON NECROLOGY

July, 1946

The Committee on Necrology regrets to report the death of several members of the Academy. The information for the accompanying biographical sketches has been kindly furnished by close friends of the members mentioned.

WILLIAM MORTON BARROWS

On February 24, 1946, the Ohio State University lost one of its outstanding teachers by the death of Professor William Morton Barrows. He had been in ill health for two years and had voluntarily retired to the rank of Professor Emeritus on August 30, 1945.

Professor Barrows was born April 7, 1883, at Rochester, N. Y. He was the son of the late Professor Walter Barrows of Michigan State College, East Lansing, Mich. In 1903 he graduated from Michigan State College with the degree of B. S. In 1905–1906 he attended Harvard and earned the degrees of B. S. and M. S. He returned to Harvard and received the D. Sc. degree in 1920. While a student in Cambridge he met Miss Eleanor S. Burton whom he married June 25, 1908. They had two sons, Dr. W. Morton Barrows, Jr., professor of physics in the University of Florida at Tallahassee, and Major Arthur B. Barrows of the U. S. Marines, who lost his life during the recent war.

From 1906 to 1907 Professor Barrows was professor of science in the North Manchester College, Indiana. From 1907 to 1909 he was instructor of zoology in the New Hampshire State College, Durham, N. H. In 1909 he joined the staff of the Ohio State University in the department of Zoology. In 1923 he gained the rank of professor. In 1929 he became supervisor of general zoology which position he held until his retirement.

Dr. Barrows was the author of *Science of Animal Life*, a text for high schools, and of numerous shorter papers on various phases of biological science. His special research was on the taxonomy of spiders in which field he became widely recognized as one of the few authorities. His library of spider literature and his collection of type forms, among the best of the world, are now in the possession of Ohio State University.

Among his most outstanding characteristics were a jovial personality, a keen wit, and the ability to induce his students to think clearly about their work.

NEVIN M. FENNEMAN

The State of Ohio and the nation both lost one of their leading scientists through the death of Dr. Nevin M. Fenneman on July 4, 1945. Dr. Fenneman was born in Lima, Ohio, December 26, 1865. He was graduated from Heidelberg at Tiffin in 1883 with the degree of A. B. From that time until 1900 he taught in various secondary schools. In 1901 he received his Ph.D. degree from the University of Chicago. Following that he became Professor of Geology at the University of Colorado in 1902 and also joined the United States Geological Survey. From 1903 to 1907 he was Professor of Geology at the University of Wisconsin and also served as geologist on the Wisconsin Geological and Natural History Survey. From 1906–1908 he was geologist with the Illinois Geological Survey. In 1907 he was called to the University of Cincinnati where he organized the Department of Geology and Geography. There, during the years he developed numerous geologists.

In addition to his other activities he served on the United States Geological Survey for over a quarter of a century. Among his outstanding contributions was a two-volume work on the Physiography of the United States. Among the offices held and the honors which came to him were the following: president of the American Association of Geologists, of the Yellowstone-Bighorn Research Association, and of the Geological Society of America; vice-president A. A. A. S. section for geology; representative of the United States at the Pan-Pacific Science Congress held in Tokyo; Gold Medalist Geographical Society of Chicago; honorary LL. D. from the University of Cincinnati. He was a member of Sigma Xi, Phi Beta Kappa, and the American Society of Naturalists.

One who knew him well wrote: "His stern teaching, his kindly, searching criticism, his keen encouragement and his own deep humility, all left their mark. He was the last of the great trio of American physiographers—Daves, Fenneman and Johnson."

FRANCIS N. MAXFIELD

Francis N. Maxfield, professor of psychology at Ohio State University, died suddenly November 10th, 1945. He had been a member of the faculty since 1925. Born sixty-eight years ago in Sandwich, Massachusetts, he received his A. B. from Haverford in 1897 and his Ph. D.

from Pennsylvania in 1912. In the period between these degrees he taught at the secondary level. This was followed by six years on the faculty at the University of Pennsylvania, two years as psychologist in the Newark, New Jersey, Public Schools, and five years as director of special education for the state of Pennsylvania. At Ohio State his principal activities involved teaching courses dealing with deviates and with psychometrics, carrying a portion of the service load in the psychological clinic and providing liaison with outside agencies needing psychological help such as the Children's Hospital and local courts. His research interests dealt particularly with feral children and with children reared in isolation. His avocational interests centered around the bridge table and the flower garden. His influence will still be felt through the students who majored under his direction and in the numerous clients whose life adjustments benefited from his counsel.

Submitted for the Committee,
FREDERICK H. KRECKER.

RESOLUTION ADOPTED BY THE OHIO ACADEMY OF SCIENCE MAY 3, 1946

"In recognition of the general facility and hospitality freely offered by The Ohio State University, and the extensively effective labor expended by the local committee, be it

"*Resolved*, that the Ohio Academy of Science formally acknowledge these excellent advantages and express its gratitude to the committee and the administrative officers of the University for the entire provision that has made possible this highly successful meeting."

BOOK NOTICE

Mosquitoes of Southern United States

This is one of the most welcome and useful monographs to reach the reviewer s desk for quite some time. It is a well written and well arranged authoritative account of the mosquitoes of the region indicated by the title. It will be an invaluable aid to every entomologist.

The book begins with an account on the life history of mosquitoes in general and their relation to diseases of medical importance. This is followed by techniques for collecting eggs, larvae and adults; transporting, mounting, and storing larval and adult stages; preparing specimens for study; dissection for malarial parasites; rearing methods, and techniques for identification with the characters of eggs, larvae, pupae and adults used for this purpose. The family Cubicidae is then presented with keys to subfamilies and tribes for the larval, pupal and adult stages, followed by keys to species for each genus. Seventy-one species are recorded for the region. A bibliography of 188 references and an index completes the book.—*R. H. Davidson.*

Mosquitoes of Southern United States, by Stanley J. Carpenter, W. W. Middelkauff and Roy W. Chamberlain. 292 pages, May, 1946. American Midland Naturalist Monograph No. 3. University Press, Notre Dame, Ind. $4.00.

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THE TEAYS RIVER

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ABSTRACT

The course of the Teays River, a large Tertiary stream, including the present Kanawha and New Rivers and their tributaries, has been traced from its source in the Piedmont region, westward to the Illinois River. This stream, more than 800 miles long, crossed the entire Appalachian region, passing through the abandoned valley, from a point near St. Albans to Huntington, West Virginia. From Chillicothe, Ohio, the buried valley of the Teays has been traced, by means of well records, in a westerly direction across Ohio, Indiana and Illinois to the Mississippi. The Teays River was a mature stream and drained a maturely dissected region. An early glacier, Kansan or pre-Kansan, dammed its westerly course in Ohio, ponding the waters, forming lake-like expanses in southeastern Ohio. In the ponded areas, slack-water deposits were laid down. The broad valley of the Teays (Kanawha-New) River was an avenue for the migration of plant life from the Piedmont region to southeastern Ohio.

INTRODUCTION

W. C. Tight[1] was the first to discuss the drainage modifications of southeastern Ohio and to trace the course of the Kanawha River through the abandoned Teays valley in West Virginia to Chillicothe, Ohio, where it disappears beneath the glacial drift. The writer,[2] by means of well records, was able to trace the course of the buried Teays valley in a northwesterly direction from Chillicothe to St. Marys Reservoir in Mercer County, Ohio, and to the Indiana state line. The course, westward through Indiana was traced by Fidlar,[3] by means of well records, and roughly follows the Wabash River to its outlet. Horberg,[4] of the Illinois State Geological Survey, established the existence of a large buried valley which he named, "Mahomet River," extending westward from the Illinois-Indiana state line, through central Illinois and entering the well known bedrock valley along Illinois River, formerly occupied by the ancient Mississippi.

Fidlar[3] traces the preglacial Teays Valley through Fountain County, Indiana, some distance east of Wabash River, to join the present valley south of Covington.

Horberg[4] proposes an alternative hypotheses in which he suggests that the main valley turned west, near Lafayette, Indiana, through southern Benton County into Illinois, and as Mahomet Valley, continues westward to join the bedrock valley along the Illinois River. To support his view, he states that this valley

[1]Tight, W. G., Drainage Modifications in Southeastern Ohio and Adjacent Parts of West Virginia and Kentucky. Prof. Paper, No. 13, U. S. G. S., 1903.

[2]Ver Steeg, Karl, The Buried Topography of Western Ohio. Jour. of Geology, Vol. XLIV, No. 8, 1936, pp. 918–939.

———, Thickness of the Glacial Drift in Western Ohio. Jour. of Geol., Vol. XLVI, No. 4, 1938, pp. 654–659.

[3]Fidlar, M. M., The Preglacial Teays Valley in Indiana. Jour. of Geology, Vol. 51, 1943, pp. 411–418.

[4]Horberg, Leland, A Major Buried Valley in East-Central Illinois and its Regional Relationships. Manuscript read before Section E, Amer. Assoc. Advancement of Science, 1944.

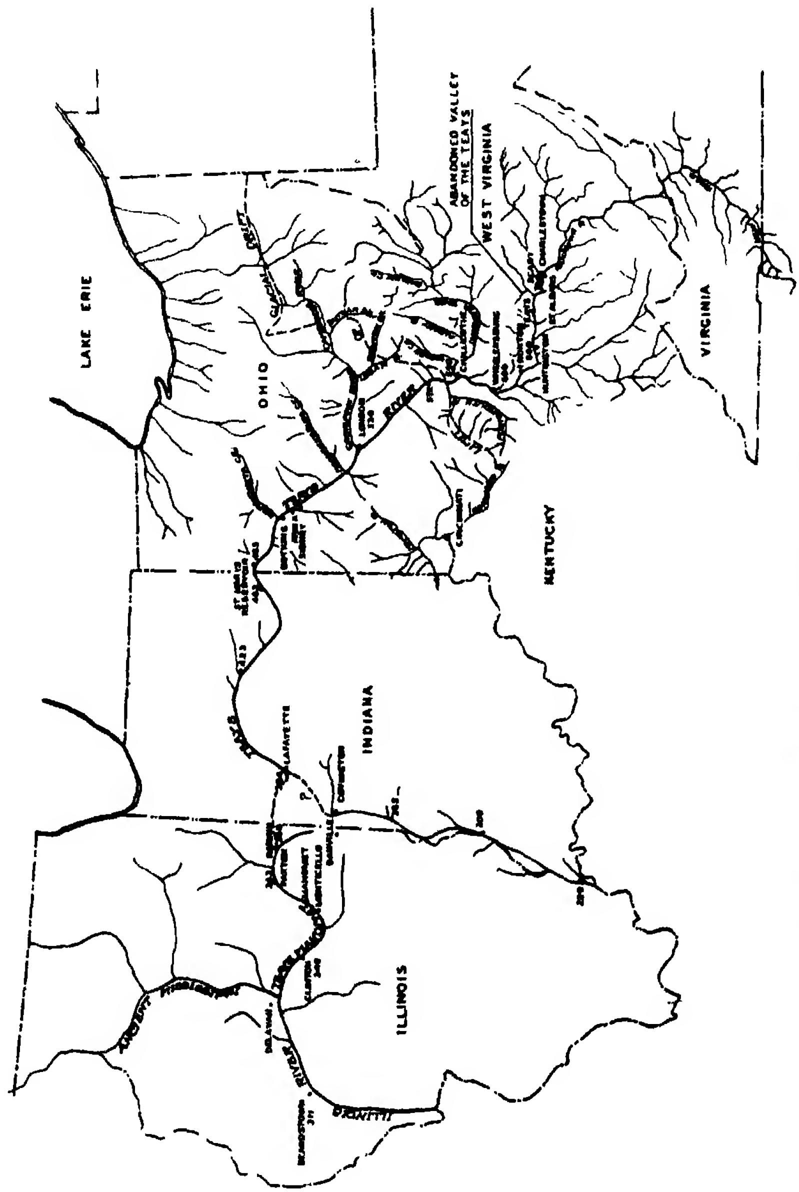

FIG. 1 MAP SHOWING TEAYS DRAINAGE SYSTEM ADAPTED IN PART FROM TIGHT, VER STEEG, FIDLAR AND HORBERG.

in southern Benton County appears to be comparable in size to the one above Lafayette; bed rock elevations to the west are lower and more closely spaced than they are to the south, where there is an interval of about 90 miles before comparable low elevations are shown by Fidlar; this interval is an area of high bedrock, as indicated by well records and bedrock exposures. Furthermore, Horberg believes that the published evidence supporting the buried valley through Fountain County is inconclusive, and points out that Leverett in a discussion of the wells of Fountain County, in Indiana, makes no reference to an important buried valley within the county. Although the details of the buried drainage lines in the Lafayette region are not clear, the existing evidence strongly indicates that the main preglacial valley of the Teays continued into Illinois.

THE COURSE OF THE TEAYS

The name "Teays" was applied by Tight[5] to the stream which occupied the broad depression known as the Teays Valley, in Cabell and Putnam counties, West Virginia. In a general sense, the term is used to indicate the period of erosion in Ohio, before glaciation. The term is applied not only to the great stream and its tributaries, but to the work of all the streams contemporary with it.[6] The immaturely developed erosion surface associated with the Teays system is known in Ohio as the Parker Strath. The Teays River, the master stream of the system, was a large preglacial river and had its source near the eastern escarpment of the Blue Ridge, at the edge of the Piedmont Plateau in North Carolina and Virginia. The New River, the southernmost tributary of the Teays River, rises in Wautauga County in the Blue Ridge area, northeast of Asheville. From thence it flows in a northeasterly direction for some distance and after making a right-angled bend, it trends northward to join the Gauley River to form Kanawha River, which continues in a northwesterly direction to Charleston. In West Virginia, the Teays received the waters of the Greenbriar River, Gauley River, Elk River and numerous minor tributaries, including a drainage area of the entire southern half of the state. In its course, the Teays River cut across the folded Appalachians, a remarkable feature which calls for an explanation as to the origin of its drainage. In addition to the waters of the New-Kanawha system, the Teays River received the major portion of the drainage from an area including one-half to two-thirds of Ohio and a large part of Indiana, Illinois and northern Kentucky. The Teays River, after passing through the abandoned valley, from a point near St. Albans to Huntington, West Virginia, extended across Ohio in a northwesterly direction; its valley buried beneath the glacial drift, continues from Chillicothe to the border of Indiana, near St. Marys Reservoir. From there, its course is westward[7] across northern Indiana to the eastern border of Illinois,[8] where it continues in a westerly direction across that state, into the bedrock valley of the Illinois River. This great stream, one of the largest of Tertiary time, was at least 800 miles long and probably longer, depending upon what evidence one accepts as to its course in Indiana and Illinois.

The significance of the abandoned Teays Valley from St. Albans, West Virginia, to Chillicothe, Ohio, and its relationship to the preglacial drainage in Ohio, was first determined by Tight.[9] This valley varies in width, from three-quarters to one and one-quarter miles, an average of a mile being about correct; its length is about 30 miles from St. Albans to Huntington. No doubt, a large stream once occupied this abandoned valley. Tight includes Flatwoods Valley, from Ashland

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[5] *Idem*. 1.
[6] Stout, Ver Steeg and Lamb, Water in Ohio. Bulletin 44, Geol. Surv, Ohio, 1943, p. 51.
[7] *Idem*., 3, pp. 411–418.
[8] *Idem*., 4.
[9] *Idem*., 1.

to Ironton, as an extension of the Teays Valley. From Huntington to Wheelersburg, the present Ohio River, which occupies this portion of the old Teays Valley, did not obliterate all traces of the former occupant, as the floor of the original valley is indicated by the extensive silted flats south of Ashland and the terraces between Franklin Furnace and Wheelersburg on the Ohio side.

At Wheelersburg, the Teays River flowed northward past Minford, Stockdale and Beaver, to Waverly, through a high-level, broad, well-defined open valley. The Scioto River has eroded and partially destroyed the Teays Valley from Waverly to Richmondale, but its floor exists as broad upland flats, near Omega and Higby. The Teays continued northward to Chillicothe, where the old valley disappears beneath a thick covering of Wisconsin drift.

From Chillicothe, the course of the buried Teays Valley, is based on well records plotted by the writer.[10] These are shown on the map (Fig. 2), and include the minimum, maximum and average depth to bedrock. Some of the wells do not reach bedrock and are indicated on the map by the letter "G." From Chillicothe, the Teays Valley can be traced in a northwesterly direction past Andersonville, crossing the southwestern part of Pickaway County, past Atlanta. From there, it crosses the extreme northeast corner of Fayette County near Waterloo, extending in a northwesterly direction past London in Madison County, to Vienna in Clark County, where the Teays was joined by a tributary, the Groveport River,[11] which drained a large area in central Ohio. From Vienna, the Teays River continues in a westerly direction, to a point near Springfield, in Clark County, and thence northwestward past Boulusville and St. Paris in Champaign County, and Sidney, Anna and Botkins, in Shelby County, to the southeastern part of Washington Township in Auglaize County, where it was joined from the north by a tributary, Wapakoneta Creek. The Teays continued its course westward past the village of Mercer to Rockford, and from there, westward to the Ohio-Indiana state line, in the northwestern part of Rock Creek Township, in Mercer County.

TRIBUTARIES OF THE TEAYS RIVER

The tributaries of the Teays, in the unglaciated area beyond the drift border in southern Ohio, exhibit the same characteristics shown by the master stream; the adjacent hills are considerably reduced, the tributaries have low gradients, broad valleys for the size of the streams which occupied them, and dendritic pattern, all features of maturity. The largest of the tributaries in Ohio[12] are the Marietta River, Hamden Creek, Albany River, Barlow Creek, Portsmouth River, Logan River, Bremen Creek, Putnam Creek, Cambridge River, Groveport River, Mechanicsburg Creek, and Wapakoneta Creek.

In his paper[13] on the Teays River in Indiana, Fidlar mentions a number of tributaries which have been partially traced. From the size of these streams, it appears that the Teays River drained a large area in northern and central Indiana. Horberg,[14] who traced the Teays River across Illinois, shows a tributary from the north which entered the Mahomet Valley near Paxton, and important tributaries from the south, north of Danville, and in western Logan and Menard counties. Tight[15] shows a tributary, called the Cincinnati River, flowing northeastward from the southwest corner of Ohio, to Dayton, to join the Teays River. There is evidence[16] that the drainage in the Miami basin, just before the advent of the ice age,

[10] *Idem.*, 2.
[11] *Idem.*, 6, Map of Teays Drainage, p. 50.
[12] *Idem* , 6, pp. 57–70.
[13] *Idem.*, 3, pp. 412, 413, 416, 417.
[14] *Idem.*, 4.
[15] *Idem.*, plate I.
[16] *Idem.*, 2, p. 927.

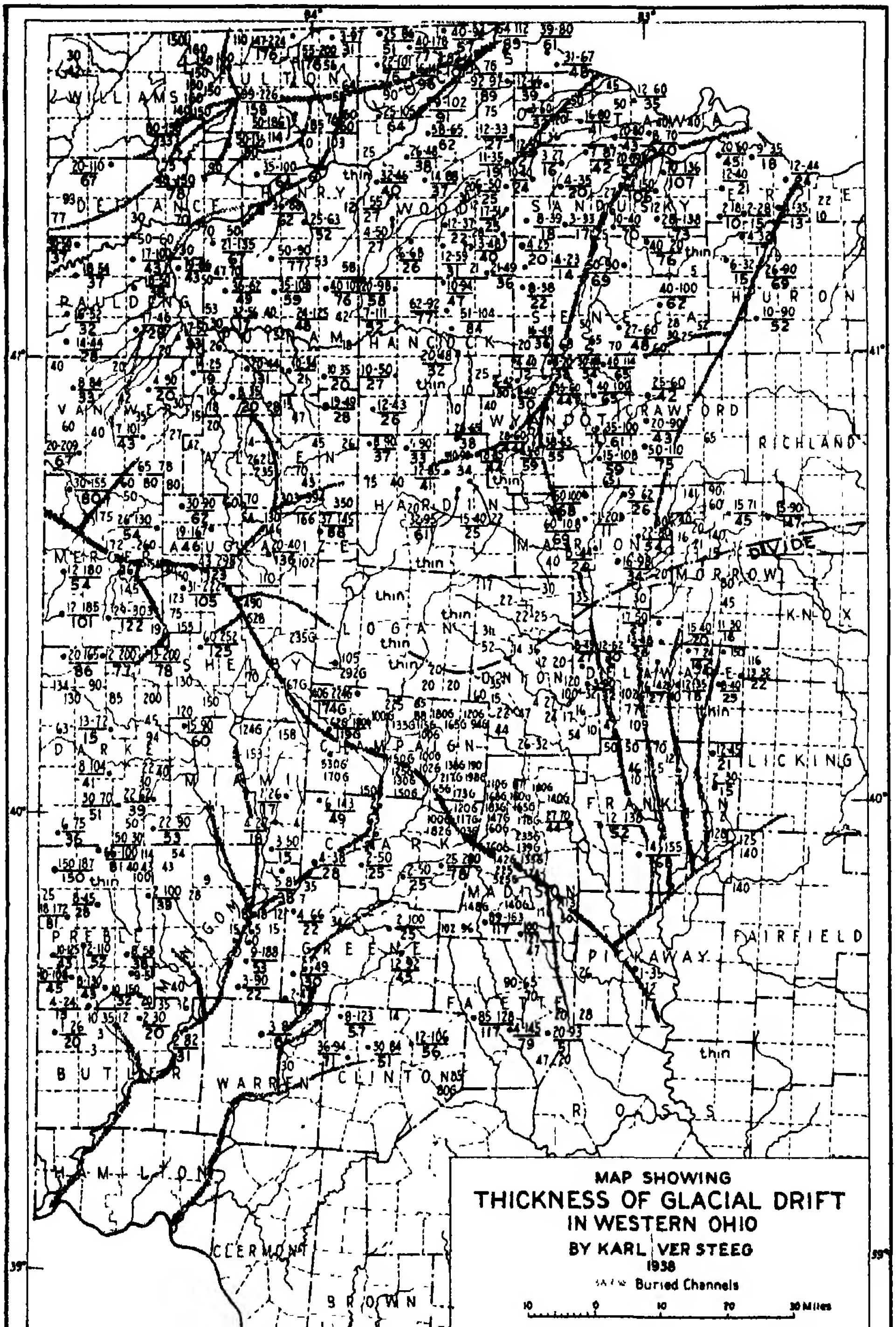

Fig. 2. Map showing the buried valley of the Teays River and other streams in Ohio. Figures above the line indicate minimum and maximum thicknesses. Figure below the line represents the average thickness. The letter "G" indicates that bedrock was not reached.

was southward as it is today. This evidence is based on the general slope of the bedrock surface in the Miami basin. It appears that a divide existed between the preglacial Teays and the Miami watershed. Well records do not indicate a broad depression which widens northward and is of sufficient size to have accommodated so large a stream as the Cincinnati River.

STAGE OF DEVELOPMENT IN THE CYCLE OF EROSION

The Kanawha Valley at St. Albans, West Virginia, is about the same size as the Teays Valley; an average width of about a mile. The stream that occupied the Teays Valley from St. Albans to Wheelersburg, Ohio, was nearly the same size as the Kanawha River near St. Albans and Charleston, which is smaller than the present Ohio River. The buried Teays Valley in Ohio may have a width of as much as five miles, in places.

Fidlar[17] does not give the width of the Teays Valley in Indiana but indicates that it is a broad depression.

Homberg[18] states that the inner portion of the buried Teays (Mahomet) River valley lying below elevations of 450 feet, is about four miles wide near the east state line, five miles in central Piatt County and about fifteen miles in DeWitt County; although the valley walls cannot be sharply drawn in most places because of the lack of detailed data, a notable widening is indicated for the downstream portion of the valley. He also indicates[19] that the valley of the Teays (Mahomet) River in Illinois was mature and cites the relative width and depth and the wide distribution of low elevations in DeWitt County, which suggest the presence of a floodplain.

Tight[20] believed that beginning with the old Tertiary peneplain as a base, a very long cycle of erosion produced the topographic features of the Teays Valley and its well-graded floor, which must have stood near base-level for a considerable length of time. Although there is little evidence for the stage in the erosion cycle of the buried Teays Valley in Ohio, it is assumed, from the appearance of the abandoned valley from St. Albans to Chillicothe, and from the width of the buried valley as determined by well records, that it was in the mature stage. Fidlar[21] states that the Teays Valley had reached the stage of maturity before the advent of the Pleistocene ice sheets.

The bed rock of the Teays Valley has an altitude of about 700 feet at Scary on the Kanawha River; 660 feet at Huntington, West Virginia; 650 feet on Dogwood Ridge near Wheelersburg, Scioto County, Ohio; 645 feet near Glade, Jackson County; 640 feet near Givins, and 630 feet at Omega, Pike County; 610 feet near Vigo, 592 feet at Schooleys, and 590 feet at Chillicothe, Ross County; 572 feet near Atlanta, Pickaway County; 530 feet near London, Madison County; and 465 feet under St. Marys Reservoir in Mercer County. The gradients and floor levels of the tributary streams conform quite well, indicating that the elevations along the floor of the buried Teays Valley are approximately correct.[22]

From Huntington, West Virginia, to Schooleys, near Chillicothe in Ross County, a distance of about 90 miles, the rock floor of the Teays Valley descends about 9 inches to the mile. From Schooleys to the St. Marys Reservoir, the distance is about 133 miles and the fall of the rock floor is 132 feet, or nearly one foot per mile. From Huntington to the St. Marys Reservoir, a distance of 233 miles, the gradient is 10.76 inches per mile.

[17] *Idem.*, 3.
[18] *Idem.*, 4.
[19] *Idem.*, 4.
[20] *Idem.*, 1, p. 56.
[21] *Idem.*, 3, p. 412.
[22] *Idem.*, 6, p. 53.

The bedrock elevations along the Teays Valley in Indiana, according to Fidlar,[23] are as follows: Jay County, 463 feet; Miami County, 423 feet; Lafayette, Indiana, 384 feet; Oxford, Benton County, 300 feet. According to Fidlar,[24] the Teays Valley in Indiana, had a gradient of approximately 8 inches per mile; the bedrock floor drops from an altitude of 463 feet in northwestern Jay County, to an altitude of 229 feet in southwestern Posey County.

In Illinois, the elevations along the floor of Teays (Mahomet) Valley, according to Horberg,[25] are as follows: Rankin, Vermilion County, 358 feet; Paxton, Ford County, 343 feet; Clinton, DeWitt County, 340 feet; Beardstown, Cass County, 311 feet. This is a fall of 47 feet. A gradient of 7 inches per mile is indicated for that portion of the Teays above Beardstown, Illinois.

From all the evidence, such as the great width and low gradient of the Teays Valley, and the bordering hills, which are well-rounded and graded, one would assume that it was in the mature stage of the cycle of erosion. Everywhere, in West Virginia, central and southern Ohio, the adjacent hills were reduced and the land highly dissected in dendritic pattern. In preglacial time, in western Ohio, on the easily eroded shales and limestones which were peneplaned, the valleys in the Teays stage were broad, such as would exist in a region worn down to an advanced stage of erosion. From North Carolina to Chillicothe, Ohio, the New-Kanawha River is entrenched below an extensive erosion surface which is known as the Harrisburg peneplane. The erosion level, known as the Parker Strath and also as the Teays surface, is younger and does not appear to be developed to any great extent in the Allegheny Plateau province in Pennsylvania and West Virginia. What surface it is correlated with, in the folded Appalachians, is not determined. The Parker Strath represents the immature peneplane or partially developed base-level evolved in Teays time. This erosion surface should be more extensively developed in western Ohio on the widespread, weaker limestones and shales of Silurian and Devonian time. Furthermore, the vertical distance the streams had to cut down to reach grade or base-level, was less than farther east in the Allegheny Plateau area, where harder Mississippian and Pennsylvanian sandstones and conglomerates stand higher and offer more resistance to erosion. The original slope of the Appalachian Plateau was toward the east as it is today, and the first streams probably worked headward from the west and northwest.

In Ohio, the buried Teays Valley is entrenched below an upland surface. At the London Prison Farm, located northwest of London, in Madison County, Ohio, one well record shows that the drill penetrated 525 feet into glacial material and did not reach bedrock. A short distance to the east, another well record shows a depth of only 324 feet to bedrock. Here, the wall of the buried valley is steep and makes a sharp break with the old surface. A study of the well records indicates a deep valley (Fig. 2), comparatively narrow in places, with rather steep sides. In Shelby County, near the town of Anna, a deep, narrow valley is indicated by well records, showing more than 500 feet of glacial drift. To the east and west of this channel, the elevation of the bedrock is about 800–900 feet. A deep, and comparatively narrow valley is indicated by the well records in Mercer County at St. Marys Reservoir, the surface bordering the trough standing at 700–800 feet.

Fidlar[26] states, that in Indiana the well records show that the bedrock surface slopes gradually toward the Teays Valley, and that this slope becomes abrupt at the site of the rock trough. He points out, that near central Blackford County, the bedrock surface drops more than 250 feet in less than one-fourth of a mile. The bedrock upland in this vicinity has an altitude of approximately 800 feet above

[23] *Idem.*, 3.
[24] *Idem.*, 3, Abstract, p. 411.
[25] *Idem.*, 4.
[26] *Idem.*, 3, p. 415.

sea-level and the valley floor is at least 350 feet lower. Fidlar's figures on the depth of the Teays Valley do not indicate that it is shallow with gently sloping sides. In Illinois,[27] the bedrock elevations along the buried valley are less than 400 feet above sea-level, or 200 to 300 feet lower than the elevations on the adjoining bedrock uplands. Its average depth is given as about 200 feet. According to Horberg,[28] there is a suggestion that the Teays Valley, in Illinois, may have been eroded during two cycles, as the inner valley is entrenched below a broad, outer valley. This is indicated by the pronounced break in slope below the 550–500 foot contours and by the absence of comparable low elevations outside the inner valley. The Teays Valley becomes broader to the west, which is as one would expect. It appears that the buried preglacial bedrock surface on the uplands along the Teays in Ohio and Indiana, is the equivalent of the same buried surface in western Ohio, which is believed by some geologists to be the same as the Parker Strath. This surface was developed in late Tertiary time and has been called the Teays erosion surface,[29] since it was developed along that preglacial stream and its larger tributaries, just before the advent of the Pleistocene ice-sheets.

The most striking features of the topography of the area drained by the Teays River, from its source and across the folded Appalachians, through the Allegheny Plateau and southeastern and central Ohio, are the upland peneplane, the mature valleys of the old cycle, the deeply cut trenches of the present drainage, and the terrace fillings in the bottoms of those trenches. A summary of the events which took place in southeastern Ohio are: (1) the reduction of the region to the base-level of the early Tertiary peneplane (Harrisburg); (2) the elevation of the early Tertiary peneplane and the rejuvenation of the mature drainage, with the entrenchment of the streams in deep valleys, which retain the meanders of the ancestral streams; (3) the gradation of the drainage, with the development of mature topographic features and the reduction of the upland peneplane (Harrisburg), with the development of dendritic drainage; (4) slack-water conditions, produced by the Kansan or pre-Kansan ice-sheet, with the widespread deposition of silts up to the present elevation of 860 feet and to a depth of as much as 80 feet or more in places, and many deflections of drainage from the old lines; (5) rejuvenation and deep erosion of the new lines of drainage below the level of the old system. This period of erosion is known as the Deep Stage[30] and is interglacial, beginning with the Kansan or pre-Kansan ice-sheet and closing with the advent of the Illinoian glacier; (6) interruption of the Deep Stage and the filling of the valleys with Illinoian till, glacial gravel trains and silts; (7) the erosion of the valley fillings and the cutting of the intermediate terraces to the depths of the present streams; (8) Wisconsin glaciation and filling of the valleys with till and outwash; (9) the reduction of the volume of the streams and continued stream action to the present time under existing conditions. From the inauguration of the Kansan or pre-Kansan ice-sheet, the Teays drainage system in Ohio was tremendously changed, during the advance and retreat of the Illinoian and Wisconsin glaciers.

CORRELATION OF EROSION SURFACES IN ILLINOIS

According to Horberg,[31] a preliminary study of the erosion surfaces in Illinois suggests that the Teays (Mahomet) Valley is entrenched below the level of a surface which is probably younger than the Dodgeville or southwestern Wisconsin. In the Havana region, the inner valley of the buried Teays (Mahomet) River appears to be eroded below the level of a still younger strath, which is about 500

[27] *Idem.*, 4.
[28] *Idem.*, 4.
[29] *Idem.*, 6, p. 51.
[30] *Idem.*, 6, p. 78.
[31] Horberg, Leland, Communication by letter.

feet above sea-level. Similar straths are present in the Kaskaskie and Wabash basins. Horberg finds no evidence of important bedrock erosions during the Yarmouth interglacial epoch, which would correlate with the Deep Stage in Ohio. He believes Mahomet Valley was eroded to its maximum depth in pre-Kansan and probably pre-Nebraskan time. He points out that the strath in central Illinois occupies a position similar to the Parker in Ohio. He suggests that perhaps the pre-Kansan entrenchment did not reach headward as far as Ohio.

PONDING OF THE TEAYS RIVER

From Franklin Furnace, in Scioto County, to Chillicothe, in Ross County, Ohio, parts of the old Teays Valley show good exposures of silts; sandy silts near bedrock and very finely laminated Minford silts at the higher levels. The materials that may be present in the deposits are coarse matter, fine-grained sand, siliceous and ferruginous silts, very fine-grained laminated silts and heterogeneous outwash from side streams. A study of the deposits in the Teays Valley and its tributaries indicates that some material must have come from the metamorphic and igneous rocks as far east as the Piedmont Plateau. These deposits also occur in the abandoned valley of the Teays from Scary to Huntington, West Virginia.[32] It is believed[33] that the advance of the Kansan or pre-Kansan ice-sheet to central Ohio blocked the westward course of the Teays River and other streams flowing northward, causing them to seek new outlets south of the edge of the ice. The drainage was considerably modified and long, marginal finger lakes were formed in which were deposited the slack-water Minford silts. They were deposited in rather deep quiet waters which were ponded to lake-like conditions throughout the valleys. The ponded water must have existed for a long time, sufficient for at least 80 feet of silt and sand to accumulate. This silt filled the valleys to a level not far from 900 feet. The ponded area was of great size and although its southern and southwestern boundaries at the time of its maximum depth are not clear, it probably extended as far west as the Licking Valley of Kentucky, as far east as the present Kanawha River in West Virginia, as far north as northern Ross and Athens counties, and 40 to 50 miles south of the present Ohio River. In Kentucky, a number of glacial boulders of large size and Canadian origin have been discovered by geologists above an altitude of 900 feet, and more than 50 miles south of the known glacial boundary. One glacial boulder, estimated to weigh about 16 tons[34] lies at an elevation of 1009.3 feet. Because this altitude is well above the 900-foot level, which is believed to be the approximate elevation of the ponded water, geologists have been puzzled as to how this huge erratic could have been laid down at its present level, even though it was rafted by an iceberg. It might be assumed that the level of the water may have fluctuated in elevation, and under certain conditions an iceberg or mass of floating ice may have reached that altitude. All the silt deposits are at, or below, a level of 860 feet. The waters which fed the ponded area was drainage from the plateau and melt-water from the Kansan or pre-Kansan ice-sheet, located to the north. Such a marginal lake must have been subject to fluctuations in water level, because of the floods due to heavy rainfall and melting snows on the plateau, as well as rapid melting of the ice-sheet. The great accumulation of slack-water deposits, to a level of 860 feet, buried the old preglacial valleys and underlying topography. When the lake was drained, many of the streams did not return to their former courses. New outlets were opened to the Ohio River. These streams followed old drainage lines where they still

[32]Stout, Wilber, and Schaaf, Downs; Bulletin Geological Society of America, Vol. 42, pp. 665–666, 1931.

[33]*Idem*.. 6, p. 78.

[34]Jillson, W. R., The Early Pleistocene Glaciation in Northeastern Kentucky. Bulletin Geological Society of America, 50, 1931.

existed, and cut new channels at many places. The ponding of the valleys in front of the Kansan or pre-Kansan ice-sheet caused considerable disarrangement of the preglacial drainage lines. Through obliteration of the lower courses of the Teays streams by glacial action and through flooding of the remaining parts of the courses, new drainage lines were established by the ponded waters seeking new outlets to the sea. These new streams are known as the Deep Stage drainage of post-Kansan or post pre-Kansan age. They cut youthful valleys below the Teays drainage level.

The major events in the drainage changes as put forth in part by Tight[35] and later, with modifications by Stout, Ver Steeg, and Lamb,[36] are as follows: The first event was the advent of the Kansan or pre-Kansan ice-sheet, which blocked the streams which flowed in a northwesterly and northward direction. This resulted in the formation of a large stretch of ponded water in the valleys of the Teays River and its tributaries, in Ohio and West Virginia, and the Licking River system in Kentucky. Thick accumulations of slack-water silts were deposited in this lake-like body of water. This resulted in the development of new outlets, modification and reversal of drainage. Later events include the advances of the Illinoian and Wisconsin ice-sheets and the modification of the silts, sands and clays. In pre-Illinoian time, during the interglacial epoch, known as the Deep Stage, the Ohio River and its tributaries cut their valleys to greater depth. Subsequently, interglacial and present day streams produced terraces by erosion of the slack-water filling in the valleys.

THE TEAYS VALLEY AS AN AVENUE FOR PLANT MIGRATION

Transeau[37] points out that the ponding in southern Ohio would have a profound effect on the vegetation of the area covered by the silts. The submerged vegetation would be destroyed and there was a complete change in the soils, to which plants that survived on islands and peninsulas may have subsequently migrated. When the streams flowed northward, in preglacial time, the soils of the submerged area were derived from the sandstones and shales of the plateau. When the ponding took place, the streams from the glaciers carried calcium and magnesium carbonates from the limestone area of central and northern Ohio. It was not until the silts were removed by erosion, that many of the plant habitats were removed and developed their present characteristics. Transeau believed that there are many localities in southern Ohio where, for example, the rhododendron might be expected to grow but in which it is absent. According to Wolfe,[38] southern plants reached Ohio along the hilltops and ridges of the Cumberland Plateau, across the route of the present Ohio River, and by way of the flood plains and adjacent bluffs of the preglacial Teays River system, the headwaters of which reached far to the southeast into western North Carolina. It is believed that the Teays and other rivers with headwaters in the Appalachians have been effective agencies of migration and it is probable that many southeastern species of plants were living in the plateau section of Ohio before the advent of the ice in Pleistocene time. Wolfe[39] points out that a large number of isolated Appalachian and southern species of plants are known in the southern Ohio area. Their arrival, isolation in well-defined areas, and their persistence, are doubtless associated with the succession of events in the physiographic history of the region.

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[35] *Idem.*, 1.

[36] *Idem.*, 6, pp. 51–106.

[37] Transeau, Edgar Allen, Prehistoric Factors in the Development of the Vegetation of Ohio. Ohio Journal of Science, Vol. XLI, No. 3, May, 1941, pp. 207–211.

[38] Wolfe, John N., Species Isolation and a Preglacial Lake in Southern Ohio. Ohio Journal of Science, Vol. XLII, No. 1, Jan. 1942, pp. 2–12.

[39] *Idem.*, 38.

ORIGIN OF THE TEAYS (KANAWHA-NEW) RIVER

The upper section of the Kanawha is known as the New River and its headwaters may be said to be almost on the Atlantic slope, for they lie on the southeastern side of the Blue Ridge Mountains in North Carolina. Tight[40] mentions the Kanawha River as being antecedent to the Appalachian uplift. The slope of the ridges and hilltops in the Appalachian province, toward the Kanawha-New River, indicates that the Schooley and Harrisburg surfaces had a marked inclination toward the trunk stream and its major tributaries. The broad sags on the ridge crests throughout the Appalachians, below which the major streams have cut their gaps, represent the old valleys on the Schooley surface. It is evident that the courses of the major streams in the Appalachians, including the Kanawha-New, were established during or before the Schooley cycle. It appears to be impossible for the streams in the folded Appalachians to have been superposed on the Schooley penoplane, a surface of considerable relief.[41] The Delaware, Susquehanna, Schuylkill, Lehigh and Potomac rivers cross hardrock ridges in their course eastward to the Atlantic. One of the theories for the origin of the courses of these streams has been explained by regional superposition on an extended coastal plain cover[42] over a peneplane earlier than the Schooley.

The Kanawha-New River, a major stream, crosses the entire folded Appalachian belt. Its course is one of the most remarkable in the Appalachian region. In all the discussions concerning superposition in the Appalachians, little has been written as to the origin of the Kanawha-New drainage across the ridges. For one to explain the courses of the major eastward-flowing rivers in the Appalachians as inherited from a superposed cover, and attempt to use another explanation for the Kanawha-New drainage, violates all principles of logical reasoning. One must be consistent and admit that if the eastward-flowing streams in the folded Appalachians were superposed, the Kanawha-New River, in the same general area, doubtless had the same physiographic history. Johnson[43] suggests that southeast-flowing master streams of the Appalachian slope, inherited their courses from a coastal plain cover which reposed upon a peneplaned surface of pre-Schooley age and which formerly extended, in some places at least, from 125 to 200 miles northwest of the present innermargin of the coastal plain deposits.

The depth and width of the buried Teays valley in Illinois, Indiana and Ohio appear to indicate a large and old stream. Its lower course must date back far into pre-Tertiary time. Since the Teays (Kanawha-New) River is entrenched below the Schooley and Harrisburg surfaces in the folded Appalachians and Appalachians and Allegheny Plateau, one would assume that an enormous amount of erosion had taken place since its original course was established. The broad sags on the ridge crests below which the stream has cut its gaps, would appear to indicate that the Teays (Kanawha-New) River existed in the Schooley cycle and perhaps earlier. Wright[44] calls attention to the fact that it is difficult to explain the westward course of the Teays (Kanawha-New) River on the Piedmont Plateau, beveled by the Harrisburg peneplane, which apparently sloped eastward. There are many unsolved problems concerning the origin of the drainage in the Appalachian region and any general consideration of such drainage problems should include the history of the Teays River, one of the largest and longest streams in the Appalachians. The course of the Tennessee across the Appalachian ridges and Cumberland Plateau also merits the same consideration. Undoubtedly, the history of all the streams in the folded Appalachians is closely related to the same general causes.

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[40] *Idem.*, i, p. 15.
[41] Ver Steeg, Karl, Annals New York Academy of Science, Vol. XXXII, pp. 87–220.
[42] Johnson, Douglas, Stream Sculpture on the Atlantic Slope. Col. Univ. Press.
[43] *Idem.*, 42, p. 133.
[44] Wright, Frank, Communication.

VARIATIONS IN THE BIRD POPULATION OF OHIO AND NEARBY STATES

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The area where most of our observations on the abundance of birds have been made includes Toledo, Bowling Green, and Sandusky, Ohio, extending 25 or 30 miles from each of these cities. In many of the species mentioned here we have evidence that similar changes have taken place over a much wider area, including northern Illinois, southern Michigan, and the western parts of New York and Pennsylvania.

EFFECT OF MODERATING CLIMATE

Temperature records in the northern states show that the average in recent years has been higher than the long time average; in other words, the climate has been moderating. How long this will continue we do not know.

At Chicago the normal or long-time average is 48.4°. In the last 18 years the annual temperature has been lower than this only once, and in the 51 years following 1893 only 8 times, but in the 33 years, 1845–1877, the annual temperature was below 48.4° twenty-two times.

At Cleveland the normal is 49.6°. Only four of the 27 years since 1917 have had a lower annual temperature.

In Ohio, taken as a whole, annual temperatures were below normal only seven times in the 25 years following 1917. In Indiana they were below the normal of 52.7° nine times in the 26 years, 1919–1944. "At Indianapolis February temperatures, 1916–1935, averaged 4° warmer than those for 1896–1915. Between February 19, 1936, and January 2, 1940, reliable thermometers did not reach zero at all; this was the first such long period without any zero weather in that city since the U. S. Weather Bureau was established." (S. S. Visher, Climate of Indiana, 1944, p. 358.)

Glaciers afford a means of knowing climatic trends for much more than one century. A period of years with more than average snowfall, and temperatures below normal, causes the ice to accumulate and move down the valley faster than it melts away, so that the ice front extends farther down than previously. When the weather becomes warmer and less snow falls the ice front retreats.

During most of the time for more than half a century glacial fronts have been retreating in all parts of the world where glaciers have been studied. On the North American Continent they are found only in the western part and little study of their motion was made until the latter part of the nineteenth century. John Muir wrote, "All glaciers that have come under my observation in southeastern Alaska have retreated and shallowed since first I became acquainted with them in 1879 and 1880."

In western Canada, Montana, and the Pacific states as far south as southern California, very few of the glaciers show evidence of advances in recent decades. Nearly all of those whose fronts have been surveyed show retreat and the rate of retreat has recently shown a marked acceleration.

In the United States "the annual losses of ice have been much greater during the 1920's and 1930's than during the decades immediately preceding. Three small glaciers in Oregon and several in California have entirely melted away in the past 25 years and those in Glacier National Park and in Montana are wasting

away at a rate which, if continued, will result in their total extinction within the next few decades." (Francois E. Matthes, Hydrology, 1942, pp. 195 and 196.)

Since the Wisconsin ice sheet started its retreat from its southern limit south of Dayton, Ohio, something like forty or fifty thousand years ago, there have been periods when both the continental glaciers and the mountain glaciers readvanced and covered again parts of the land which had been freed from its burden of ice.

Studies by botanists of the pollen in peat bogs in Ohio, Indiana, Sweden, and other parts of North America and Europe have confirmed and supplemented conclusions based on the study of glaciers. Fir, spruce, and many species of pine can stand more cold than hickory, oak, and maple. Microscopic examination of the pollen in successive layers of the vegetable matter in these bogs makes it possible to infer what changes of climate have taken place.

For thousands of years after the continental ice sheet had disappeared from the northern states the climate was milder than it is now. About 2000 B. C. conifers began to crowd back southward the deciduous trees which had long thrived in the mild climate. This cool period continued, with numerous brief interruptions, until about 1600 A. D. Then it became still colder; glaciers in Switzerland overran villages and land where forests had been growing for centuries. When our ancestors first landed in New England and New York they encountered a more rigorous climate than had prevailed there in previous centuries. In the 1850's it became much warmer and there was a rapid retreat of glaciers. Since then it has been cooler for a few years at a time, but not so cool as in the seventeenth and eighteenth centuries. During most of the past quarter century the weather has been rather mild.

Records of temperatures have been kept at a few places in the eastern part of the United States since early in the nineteenth century. Those at The Marine Hospital, Ft. Columbus, New York City, cover the period 1822–1874. In the first eight years of this record the average temperature was higher than in any decade that followed. The U. S. Weather Bureau records at New York started in 1871. They show that in that city annual temperatures continued below normal in most of the years to 1897. After that a majority of them were above normal. Likewise, in the North Central States relatively cool weather prevailed until sometime in the 1890's.

At New York City the warmest of all the decades was 1930–1939, with an average of 53.7°. In 1830–1839 the average was 2.9° lower, that is 50.8°. This corresponds fairly well with the rate of change at Cleveland where the average, 51.38°, for the period 1931–1942 was 2.13° higher than the average of 49.25° in 1856–1870. In both of these records I have made due allowance for the difference in location of thermometers. The record of Gustavus A. Hyde at Cleveland extends from 1856–1906, and so overlaps that of the Weather Bureau for many years, giving a good basis for comparison. His instruments were furnished by the Smithsonian Institution.

The range in annual temperatures is much larger than that of decades—seven or eight degrees at places with long records.

Changes of climate such as these might have little effect on the bird population in a region where nearly all of the winters are mild, but the area whose bird population we are considering lies mainly between the 40th and 43rd parallels. Throughout the greater part of it the mean temperature from mid-November to mid-March is not very far from 32°. In those winters when it is three or four degrees lower than 32° snow may be expected to cover the ground during a much larger part of the time than in those winters when it is a few degrees above 32°.

We have records of the amount of snowfall at many places since early in this century or the latter part of the nineteenth century.

Of the twenty-six years since 1918, nineteen have had less snow than the long

time average in Ohio and twenty had less in Indiana. In nine of the seventeen that were below average at Toledo the amount of snow ranged from 12.2 inches to 21.1 inches; the average, 1885–1942, was 30.4 inches.

In the winters, 1885–1886 to 1917–1918, snowfall was above average at Toledo 22 times, that is, in two-thirds of the whole number. In each of eight of these winters more than 40 inches of snow fell. In the winter of 1895–1896 there was five times as much as in the winter of 1918–1919.

In some periods of a decade or two most of the years have had average monthly temperatures in the two coldest months several degrees below 29°; in other periods of similar length a majority have had averages a few degrees above 29°. Such differences affect our fuel bills to the extent of 25% or so.

The fuel on which a bird depends is the food it eats. When the food is cold, some calories are lost in warming it. A few degrees would not amount to very much were it not for the latent heat in unfrozen food and the lack of it in that which must be thawed out inside of the bird. A large part of the food of birds yields less than 700 calories per kilogram. If the food is frozen, about 80 calories is consumed in thawing it out. A coating of frost or ice may still further reduce its value. If the bird must find and dig out the food from under the snow, its troubles are greatly increased.

NORTHERN BIRDS WHICH FORMERLY WERE OFTEN SEEN IN OHIO IN WINTER

Dr. Carl Tuttle, a former member of A. O. U., has lived in Berlin Heights, Erie County, Ohio, for more than eighty years. He writes, "I distinctly remember when I was 15 years old or so of seeing every winter flocks of Snowflakes. In the last 25 years I have not seen any."

At Three Rivers, St. Joseph County, Michigan, Oscar M. Bryens kept a record of the number of birds of each species he saw in the winters, 1925–26, 1926–27, and 1945–46. He was away in the intervening winters. He saw Snow Buntings in each of the first two winters, including 97 birds, March 3, 1926, but none in the recent winter.

Elsewhere in the latitude of Toledo these birds, as well as Lapland Longspurs, Northern Shrikes, and Northern Horned Larks were formerly seen by many bird students in winter, but in a majority of recent years they have been relatively scarce. However, the largest number of Snow Buntings ever seen in one day in the Toledo area was January 31, 1943, when Mr. and Mrs. Fred Stearns saw about 5,500 at Bono.

The Common Redpoll has been rare in Ohio for more than half a century. In Dr. Wheaton's time it was a tolerably regular winter resident in northern Ohio. Lynds Jones, who came to Oberlin in 1890, says, "Previous to my residence in Ohio this species was reported as being common in the region of Oberlin nearly every winter." The numbers of Redpolls observed in the last ten years seems to have been even less than before. In the recent winter Mr. Bryens saw none in St. Joseph County, Michigan, where he saw them on 32 days in the winter of 1925–26, 78 birds March 17, 1926.

SOUTHERN BIRDS WHOSE RANGE HAS BEEN EXTENDED NORTHWARD

"In Finland the warmer climate of the past fifty years has caused the influx of birds from the south." (Margaret Nice.) In this country the northward extension of habitat has undoubtedly been favored by the milder climate, especially in the case of those birds that winter near the northern limit of their range. A factor that may have been more potent in bringing about the change is the food supply provided by man purposely or otherwise.

In western New York Cardinals are still uncommon but increasing. There has been a notable increase all the way from Pennsylvania to Illinois. Only two of the many persons consulted have reported their numbers unchanged. In the Christmas bird census at Cleveland, 103 Cardinals were counted in 1940 and farther south at Buckeye Lake, Ohio, 309 were counted in 1943. Most of the time in winter 25 or more live within 100 yards of the home of Seymour Holloway near Swan Creek, southwest of Toledo. In 1885, when I went to Grand Rapids, Michigan, to teach zoology and other subjects in the high school, the only Cardinal which the naturalists of the Kent Scientific Institute knew about had been seen not long before in the yard of Dudley Waters. At the present time hundreds of Cardinals are living in and near that city. Milton Trautman writes, "In 1925 I found Cardinals north of Grayling, Michigan, but after the 1936 winter they seemed to have been frozen back at least 100 miles to the south."

Between 1860 and 1900 most of the families in Columbus, Ohio, are said to have had a caged Cardinal. John Frey, who then made a business of trapping Cardinals, told Mr. Trautman that trappers had extirpated these birds in a 50-mile radius about Columbus and he had to go into Adams County, Ohio, and to Kentucky to trap his Cardinals. Probably something similar occurred around other cities in about that latitude. After trapping ceased, the wild birds rapidly increased.

The cutting of the forest followed by cultivation of the land made it possible for many more Cardinals to find food. Before that, buckwheat, corn, sunflower, and many kinds of weed seeds were not available in great quantities.

When a large number of people became interested in providing food for Cardinals, the birds were quick to respond and most of the other species which were attracted to feeding shelves were unable to displace them

Wild Mockingbirds were seen throughout the year in northern Ohio and even in southern Michigan for years before the beginning of the present century. They are still scarce so far north, but have become fairly numerous in recent years in the vicinity of Indianapolis and Columbus, and have extended their range northward in Pennsylvania and New England.

Dr. J. P. Kirtland, in his catalogue of the Birds of Ohio, published in the Geological Survey, in 1838, does not include any kind of Wren; there may have been none before there were buildings in Ohio. The house wren was first noticed in Dekalb County in northeastern Indiana in 1883, and until about that time there were areas in Ohio and Michigan where they were rarely, if ever, seen. Now many make their home in the woods as well as where man has provided shelter. In the Southern States the Bewick Wren and Carolina Wren have long made their homes near buildings. The northward extension of the range of the former started as early as the 1870's and the latter as early as the 1880's. Since the extremely cold periods in the winter of 1936, the Carolina Wren has been scarcer than before. They are seen occasionally as far north as Grand Rapids, Michigan. Bewick's Wren has made a steady increase at Lancaster, Ohio, in the last four years. (Charles Goslin.) It has also increased near Cleveland. (J. P. Visscher.)

In recent years the Hooded Warbler and the Prothonotary Warbler have been nesting in the North. At many places in southern Indiana the Prothonotary Warbler was first noticed in the 1880's.

The Tufted Titmouse has long been common in a considerable part of Ohio and Indiana. In recent years the number in the northern parts of Ohio and Illinois has become very great, and they have extended their range northward in Michigan and New York State. In woods near Toledo the loud call of the Titmouse is likely to be heard oftener than that of any other bird except the Blue Jay.

Wood Thrushes in the past twenty years have been more numerous than formerly in the northern part of their range.

Robins and Blue Birds are now less rare in the North in winter than they used

to be, and the former have been unusually numerous from mid-March until late in October.

Little Blue Herons are quite irregular in their visits to northern Ohio. Some have been seen in late summer in a majority of the years since 1923. In August, 1930, nearly a hundred were observed. Very few have been seen in mature plumage.

American Egrets have been seen in the North more frequently than Little Blue Herons. Since about 1925, they have been observed in Pennsylvania and northern Ohio. For some thirty years before that they were on the verge of extermination, because women paid high prices to get their ornamental plumes. Karl Bartel reports 100% increase in the Chicago area. Bernard Baker saw American Egrets near Grand Rapids, Michigan, in 1939, 1940, and 1941, and at Grand Traverse Bay in 1940. Some have been seen at Rochester, New York, since 1933. Since 1941 relatively few have been seen along streams in northern Ohio, excepting near Lake Erie. Harold Mayfield and Louis Campbell saw 80 Egrets September 3, 1944, at Reno Beach, east of Toledo, and 104 August 22, 1945, in the Erie Marsh in Michigan, north of Toledo.

Like the preceding, the Snowy Egrets were too beautiful to be allowed to live, and were sacrificed on the altar of Dame Fashion. They have long been among the rarest of Ohio birds. Although a few nested in southern Indiana half a century ago, we have no evidence that they were ever numerous north of the Ohio River. There was some increase in their numbers in the Toledo area, 1934–1939. (Louis W. Campbell.) In these years the summers were unusually hot.

"In 1879 there were but five known records of the Barn Owl in Ohio and none in Indiana." (Amos W. Butler, The Birds of Indiana, p. 800.) Early in the present century it was no longer rare in southern Ohio and there were also many living permanently in northern Ohio. For quite a number of years past Barn Owls have been among the most numerous of the larger birds of prey in this region, and perhaps the most useful, considering their numbers, of all our many useful birds. A glance at the feet of these birds will show why they are not fond of winter weather much farther north than Ohio. They remind us of the scantily-haired opossum, which had been increasing in the North for many years prior to the hard winter of 1944–45. So many perished then that several, perhaps many, years will be needed to restore their numbers. For a long time quite a number of Barn Owls have had their homes inside of large trees on one farm traversed by Swan Creek southwest of Toledo. Apparently they all survived the winter of 1944–45. Their wings enabled them to fly quickly to good places to find food and return without long exposure to the cold.

In addition to the southern birds mentioned above, all of which are attractive or easily identified, there are other species which are known or believed to have extended their range northward, for example, Bachman's Sparrow and Carolina Chickadee. A list of birds from the Southwestern and Western States which have established homes in some of the North Central States will be found under the heading, Bird Life Affected by the Activities of Man.

For many years Mourning Doves have been common over a wide area. Since early in the present century when they were considered a game bird, their numbers have steadily increased. The extension of wheat acreage in the Northwest has made them one of the most common birds there. The number now in the whole country may exceed that of any native land bird of larger size except the crow, but probably is less than the number of Passenger Pigeons in the middle of the last century. They subsist largely on weed seeds and scattered grain, doing very little harm to crops.

One reason for the increase of Mourning Doves in recent years is the fact that those which went south to spend the winter were able to return in spring, because people there were too busy with more important matters to use their

shells in shooting birds. Moreover, they have escaped the hazards that have decimated those species that habitually nest on the ground, and their nesting season covers several months, some of which are likely to be favorable for rearing their young. Combines, which are now in general use in many states, scatter a large amount of grain. This has increased the food supply for Doves.

Milder winters and more food have induced large numbers of these birds to stay farther north than formerly. Hundreds of them remain through the winter in the Toledo area. In the 1940 Christmas census 155 were enumerated there. In central Ohio the number has been larger than this at more than one place and in more than one census. In Michigan they are often seen in winter as far north as Lansing.

EFFECTS OF WET AND DRY PERIODS

In the entire record of precipitation since the Weather Bureau started in 1871 there were no other three consecutive years in which so much rain fell in northern Ohio each spring as in 1943, 1944, and 1945. At Cincinnati rain in these three springs has not been surpassed since the early 1880's. The ground was unusually wet also in the nesting season of 1942, 1940, and 1937. Ground-nesting birds must have found it difficult to rear their young in all of those years, especially where the land is so flat as it is around Bowling Green. Hungarian Partridge and Bobwhite have become rare in the Bowling Green area; the numbers of Pheasants, Meadowlarks, Bobolinks, Grasshopper Sparrows, Vesper, and Song Sparrows have been reduced. For some of them it seems probable that unfavorable nesting conditions have been the most potent factor in bringing about the change. Decrease in some of these birds may be due also to the increase of crows and of those birds of prey which feed on birds—Sharp-skinned, Coopers, and Marsh Hawks.

The dry summers that characterized most of the twelve years from 1930 to 1941 were unfavorable for many kinds of birds. July, 1936, was hot as well as dry. At that time I spent a few hours on West Sister Island in Lake Erie, where there were thousands of nests of the Black-crowned Night Herons. On the ground under the nests there were hundreds of the young birds dead or dying. These herons do not maintain a colony in one place so long as do the Great Blue Herons. For two or three decades past they have been much more numerous in northern Ohio than they were earlier in the century. The reason is probably better protection for herons in general. In a colony north of Bay City, Michigan, in 1941, Walter P. Nickell estimated there were 300 breeding pairs.

Dry summers are unfavorable for Woodcock, Snipe, Water-thrushes, and Short-billed Marsh Wrens; their numbers have been much reduced. Other birds were affected by the poor crops. In some of these summers the yield of grain, weed seeds, and berries was much less than usual.

VAGARIES OF THE WEATHER

Some meteorological phenomena not implying any change of climate occasionally cause the destruction of large numbers of birds. On dark stormy nights at time of migration many thousands have perished by flying against light houses or beacon lights. Birds whose winter range is in the Gulf and South Atlantic States have at times encountered such bad winters there that a majority perished and five or more years were needed to restore their former numbers. This is likely to occur to birds like the Phoebe, which feed on insects they catch while flying.

Thunder storms have sometimes killed many birds in summer. In one of the little parks at Sandusky, Ohio, more than a hundred English Sparrows were found dead early one morning. They had drowned in pools of water where the ground was dry the previous evening. A heavy rain after midnight had probably chilled and weakened them. Another downpour before sunrise knocked them off their perches.

At times sleet storms have proved disastrous over a wide area. Milton Trautman's observations of Carolina Wrens in the vicinity of Buckeye Lake, Ohio, illustrate this and also a great reduction in their numbers caused by severe winters. "During a sleet storm in the winter of 1917–18 a great decrease in numbers occurred and for a few years thereafter only a few pairs nested within the 40 square mile area. By late 1923 as many as 30 individuals could be recorded daily; then that winter another sleet storm greatly reduced their numbers. Other reductions in numbers occurred in 1928 and 1930. In late 1935 I recorded 40 to 50 daily, then came the severe winter of 1935–36 and after that less than 5 per day could be recorded. The numbers rose again to 25 per day in 1941. Then the two hard winters of 1943–44 and 1944–45 so reduced their numbers that in December of 1945 only one bird could be found in the area and it was at a feeding station."

EFFECT OF INTRODUCED FOREIGN BIRDS ON OUR NATIVE SPECIES

In my boyhood days in Branch County, Michigan, in the 1870's, the familiar Chipping Sparrow nested in a bush in our front yard. They were very peaceable. The aggressive English Sparrow was unknown to us. Cliff Swallows, long common in the west, became abundant in Ohio after barns were built there, affording them nesting sites under the eaves and plenty of flies for food. English Sparrows appropriated all the good nesting places they could find around the buildings. They drove these Swallows into oblivion. They made trouble too for Purple Martins and other birds, but greatly augmented the food supply of Screech Owls and Sparrow Hawks. In recent years the English Sparrows have become less numerous. In the village of Berlin Heights Dr. Tuttle estimates that less than a hundred of these unwelcome guests still remain. Their decrease may be due partly to the scarcity of horses on the roads, but probably two other factors have had more effect on their numbers. On many farms strawstacks are no longer seen, because the harvesting of small grains is done with combines and the straw, if it is not left in the field, is baled. Those straw stacks were very useful to the Sparrows, affording them protection from storms and predators, nesting sites, and considerable food. Still more important has been the competition of Starlings with Sparrows. This began before combines were in common use in Ohio and affected both country and city.

Starlings were observed in Erie and Ottawa Counties, Ohio, by Lynds Jones in 1921. They increased year after year, although the number in the state now may not be greater than it was a few years ago. Their competition with other small birds for food and nesting sites has reduced the numbers of many species, especially those that nest in holes. They are very aggressive birds and seem to delight in persecuting other kinds. One Starling, although it is armed with a sharp beak, would not make headway against a Sparrow Hawk, a Flicker, or a Red-headed Woodpecker, but by ganging up in large numbers and attacking energetically and persistently, they succeed in driving all of these birds away from the cavities in which they would like to nest. This has been an important factor in causing Red-headed Woodpeckers to become scarce where they were formerly abundant. Decrease in the number of Sparrow Hawks in some areas may be due to the same cause, although they are not always driven away by Starlings.

In many places Flickers have decreased in numbers. In some places they have held their own, or even increased. Their eviction from nesting sites by Starlings has frequently been observed, but some have eventually found cavities where they succeeded in rearing young. They are very prolific.

Downy Woodpeckers have held their own fairly well. Suet put out by their admirers has helped them. They have also benefited, and so have the farmers, from their persistence in finding European corn borers. While working in his

corn field, Seymour Holloway has noticed in one day about a dozen of these dynamic midgets diligently searching for borers in the stalks.

In Toledo there has been a notable decrease in Chickadees and Nuthatches in recent years. Their numbers have probably been reduced also in other cities where Starlings abound.

Walter P. Nickell of the Cranbrook Institute of Science near Detroit writes me, "Not one pair of Bluebirds has nested in the numerous cavities in our old apple trees back of the Museum for at least ten years, while an average of 15 or 20 nests of the Starling are found every year. Three hundred miles farther north, in Charlevoix County, Starlings are much less common, and no competition between Starlings and Bluebirds for nest cavities has been observed. Cedar Waxwings are also numerous there."

The decrease in Cedar Waxwings has been observed over a wide area and has probably been caused by their inability to find enough fruit left by the Starlings.

In the last week of March, 1946, I watched outside my window a Mourning Dove as she brought sticks from the yard to build a nest in the crotch of an old silver maple. Despite annoyance from both Sparrows and Starlings she was able to complete the nest. A few days later I found, on the sidewalk beneath, two broken eggs which the Dove had laid. The large splotch and shell fragments from one of the eggs were still plain amid the droppings of Starlings a week later, but the Dove had not been seen in the tree since the eggs fell.

Ring-necked Pheasants had become well established in the Bowling Green-Toledo area by 1923, after several attempts to introduce them. The number living in Wood County in the late 1930's was estimated at 175,522. This means about a dozen birds for every family on all of the 4,816 farms in the county, as well as those living in Bowling Green and a score of smaller towns, villages, and hamlets. Most of these birds when they reach maturity weigh between two and three pounds. No one expects them to do this without consuming a large amount of food. Barnyard fowls, if not closely confined, obtain considerable food for themselves and in doing so damage various crops. Pheasants have to find nearly all of their food and the farmer cannot reasonably expect them to make a living on his land without molesting some of the crops he is attempting to grow.

Even if the Pheasants served no other good purpose, their usefulness in protecting crops from the ravages of insects and mice would offset what damage they do to sprouting grain and to unharvested grain. In dry seasons when water is hard to find they are likely to pick into many tomatoes and probably some melons, but melon growers have sometimes accused them of eating melons when they were really eating destructive insects. Crows also account for much damage which careless observers have assumed was done by Pheasants. Water in crocks in melon patches is said to lessen the damage done to the fruit by birds.

R. S. Phillips of the Findlay Bird Club counted 131 squash bugs which he found in a single Pheasant. They are known to eat also large numbers of cucumber beetles, cutworms, crickets, grasshoppers, and other destructive insects.

For a few years past the Pheasant population of Ohio has decreased to such an extent that after the shooting season of November, 1945, the number of birds in Wood County remaining alive and not crippled, was probably less than ten per cent of the average summer population during the 1930's. Naturally this is a matter of deep concern to sportsmen and to many farmers. An appraisal of the relative importance of the various factors that have brought about this decrease is difficult. I will give some of them in order of importance as I see it, but many persons who have had more experience with Pheasants will disagree with me.

1. The Shooting of Hen Pheasants Carelessly or Otherwise. Near Toledo a great many Pheasants have been killed out of season by poachers shooting from parked cars. In the excitement engendered by the great numbers of hunters

in the first few days of the open season some who are usually law-abiding have killed or crippled hen Pheasants.

In Wood County in the late 1930's it was found that about forty hen Pheasants were shot for every one hundred cocks bagged. In the past two years the percentage of Pheasants illegally killed has probably been still larger.

2. The Alfalfa Mill. These mills take care of a large amount of hay in a short time, using it before it is tall enough to afford good protection for the Pheasants. Much of the mowing is done with high-powered machinery, operating at night as well as through the day. At night many Pheasants are killed. Those nests that escape instant destruction are usually abandoned and the eggs exposed, to be consumed by Crows and four-footed prowlers.

3. The Clearing of the Banks of Ditches and Natural Streams. Formerly the saplings, bushes, brush, grass, and weeds were used by Pheasants and by many other birds for concealment and for nesting sites. They also found in them a variety of food different from the kinds found in the fields. In order to give employment to persons on relief, the work of clearing the stream banks was authorized by township trustees or county commissioners, and much of it by the C.C.C. and W.P.A. If this work is done before July 10, many nests and young birds are destroyed at the time, but whether it is done early in the summer or later, years are required to restore a favorable environment for wild life.

4. Foxes. Never before were there so many red foxes in Ohio or Michigan as in the past few years.

Tuscarawas County, 75 miles south of Cleveland, had paid bounties on 300 foxes less than two weeks after the commissioners had appropriated the money, January 1, 1946. Union County, 25 miles northwest of Columbus, paid bounties on 92 foxes, November, 1945, to January, 1946. Wyandot County, sixty miles north of Columbus, paid bounties on 43 foxes, November, 1945, to April 7, 1946. In each case the bounty was three dollars.

In the flat country south of Toledo, where nearly all of the land is cultivated, foxes have increased but are not so numerous as in rugged parts of the state.

5. Cats. In many of the Pheasant areas cats are believed to kill more of the young birds than are killed by any other predator. This is most noticeable near towns. Feral cats, which find their living entirely in the wild, are more numerous than most people realize. One farmer of my acquaintance killed fifteen feral cats in the winter, 1945–46, about half of them on his own land in Lucas County.

On the Stitt Game Preserve in Wood County, sixty of these pests were killed in one winter. Most of these feral cats were probably born in Toledo and smaller towns. Their owners, having too many, took them miles away to shift for themselves.

6. Hawks. Most kinds of hawks are not restricted to a diet of mammals, fish, or any one class of animals, but take what is easiest to get. Cooper's and Sharp-skinned Hawks are now numerous in areas where Pheasants abound. Near Lake Erie, Marsh Hawks are most numerous and probably take some young Pheasants, although as a rule birds form only a small part of their diet. Red-tailed Hawks have increased and are now so numerous in some counties that they are the worst offenders. In Wood County they are believed to kill more Pheasants than are taken altogether by other species of Hawks. In winter Rough-legged Hawks and Goshawks are uncommon or rare in Ohio, but both of these winter visitors have increased in recent years.

7. Crows. One farmer southwest of Toledo reports finding the shells of Pheasant eggs that had been eaten by Crows—enough eggs to fill a 3-gallon pail.

"During the period 1912–20 pest hunts were almost unknown in Wood County.

After that, thousands of crows were killed at their roosting places and the great rookery on the western edge of Bowling Green was broken up. Pheasants had a chance to hatch their eggs, and almost unbelievable increases were noted in the Pheasant counts."—(James Stitt.)

8. Bad Weather. In some years spring freshets have drowned out many nests of ground-nesting birds. The unusual succession of very wet springs must have frustrated the attempts of many Pheasants to rear their young, especially where the land was poorly drained. In the very dry summer months, with little dew and the vegetation withered, probably many suffered from lack of water.

The long cold winter of 1944–45, with the ground snow-covered most of the time, was hard on Pheasants. Many that would have perished were saved by man's aid. About 400 of the birds found their food in the standing corn on one farm near Monclova. A farmer near Whitehouse had an even larger number feeding during the winter in his field. Illness had kept him from harvesting the corn. He was partly reimbursed by sportsmen's clubs.

9. Other Egg Eaters. Bird eggs appeal to the appetite of a great variety of mammals, birds, and reptiles. For many species no other kind of food is more attractive. Pheasants protect their nests from small intruders, yet the number of Pheasant eggs devoured in the past twenty years in Wood County probably exceeds the number of hen eggs consumed by all the people of any one town in the county, except one or two of the largest.

One of the worst offenders is the opossum. Favored by mild weather for many years prior to the cold winter, 1944–45, these odd creatures had been increasing in Northern Ohio and Southern Michigan. In their nocturnal wanderings they find many Pheasant nests. Skunks also are notorious egg eaters; their destruction of Pheasant nests has been noticed in many places. However, their number in the Toledo area in the past few years has been less than formerly. Farmers have attributed this to the multitude of oppossums; they are believed to devour skunks in their burrows when they are hibernating. Because nearly all the opossums perished in the winter of 1944-45, the young skunks born later came through the following winter unmolested. At any rate skunks have recently been observed in unusual numbers.

Raccoons were quite numerous in 1945. Unlike opossums, they are well protected by fur coats and can hibernate for long periods of time in hollow trees, where they are safe from storms and traps. Opossums are southern animals and seem to be incapable of going long without food. Raccoons are passionately fond of eggs; they found many Pheasant nests in 1945.

Rats, the most destructive of all mammals, probably destroy many Pheasant nests. Stray dogs also are known to find and eat the eggs.

10. Owls. In the nesting season of 1945 Laurel VanCamp of Genoa, southeast of Toledo, found fifteen nests of Great Horned Owls. In many places Barred Owls are more numerous, but they probably do not kill so many Pheasants. A Snowy Owl was shot near Bowling Green, November 29, 1945, when it was carrying a Pheasant. Few, if any, are killed by Owls of other species.

11. Automobiles. These have maimed and killed numerous Pheasants and caused the death of others by aiding those unscrupulous persons who indulge in illegal shooting. "On one Sunday in 1941 I counted 70 dead Pheasants and rabbits between Findlay and Bowling Green; fully half of them were Pheasants."—(James Stitt).

PHEASANTS AND NATIVE BIRDS

Where there are not more than twenty Pheasants per square mile they may have little effect on the numbers of the other species present, but in Wood County

there have often been two or three hundred for each square mile of farm land. They have caused a large increase in the number of Hawks, Owls, and Crows, and a decrease in those species which naturally eat the same sort of food.

In Wood County in 1945 James Stitt, who for many years has spent most of his time in producing and maintaining the large Pheasant population, received the following reports of birds of prey, mostly from men in the feeding stations: Hawks shot, 671; trapped, 33; Owls shot, 19; trapped, 41. The whole number killed in 1945 within thirty miles of Bowling Green probably exceeded three thousand, including those killed by poultry-raisers.

Pheasants have been seen eating the eggs of Bobwhites and Meadowlarks, although they may not search for them, nor find enough to change materially the number of successful nestings. Birds whose decrease is probably due in part to the abundance of Pheasants are Meadowlarks, Bobolinks, Grasshopper Sparrows, Vesper Sparrows, and Bobwhites. Even the Sparrow Hawks are less numerous where Pheasants are abundant, probably because their food supply is reduced both by the Pheasants and by the numerous large birds of prey that feed on the Pheasants.

For some years past the increase in the number of predators has been greater than the increase in Pheasants. "The proportion (of predation) rises and falls progressively with increase or decrease in numbers of the available food organisms." —(W. L. McAtee).

The great number of Hawks, Great Horned Owls, Crows, foxes and other predators in the past ten years may have been more effective in reducing the number of Bobwhites, Hungarian Partridges, Meadowlarks, and other species in the areas having a high concentration of Pheasants than the reduced food supply caused by their presence.

The following abridged statements show some of the conclusions of Professor Paul L. Errington of Iowa State College relative to competitive relations of Ring-necked Pheasants and Bobwhites.

"Wintering Bobwhites avoid coverts having many Pheasants, much as they do places overpopulated with their own kind.

"Even very low densities of Pheasants have their competitive significance to the Bobwhite.

"Pheasants have displayed vastly more tolerance of crowding than have the Bobwhites."

Both of these valuable birds suffer in cold winters when there is deep snow, unless they can get to ample food supplies provided by man. Of the two the Bobwhite is less hardy and succumbs more quickly to lack of food. Its chief advantage over its competitors in Ohio is that it is protected from shooting. Most of the farmers realize that it is highly beneficial to crops and does little or no harm. In large parts of the state where Pheasants have not been numerous, the Bobwhites were holding their own prior to the severe winter of 1944–45.

In Michigan also the shooting of Bobwhite is illegal, and its range has slowly extended northward as far as the Strait of Mackinac.

Crows are not foreign birds, but as trouble makers they are unsurpassed. They have not been scarce within our recollection and have shown a marked increase in Ohio in recent years, despite the fact that a great many have been shot. Their damage to crops has been very great, in many places greater than that of any other birds. They ruin tomato crops by picking into one fruit after another as soon as it turns red. They eat sprouting corn to such an extent that much replanting is necessary to get a fair crop. In some wet seasons tons of ripening corn have been ruined in a single field by crows which open the husk and eat the kernels near the top of the ear, leaving the remainder to be spoiled by beetles and fungi. They have continued to seize the eggs and young of various other birds.

The increased amount of animal protein available for them has enabled them to produce and feed more young crows. They watch ducks when they are at a distance from the farm buildings and take their eggs as soon as they are laid.

One Toledo hunter, loading his own shells, claims to have shot nearly a thousand crows in the season of 1944–45. I know a farmer who shot at least 150 in the spring of 1945. Some other farmers would have done this if they had had enough ammunition. In general the farmers are grateful to anyone who succeeds in killing crows. A few years ago, when shells were supplied to crow hunters by the state, Max Kempker of Toledo shot between six and eight thousand of these pests each year.

BIRD LIFE AFFECTED BY THE ACTIVITIES OF MAN

Decrease.—Decrease in the numbers of many kinds of birds has been caused by man. The cutting down of forests deprived numerous species of their natural habitat. Because of its great fertility, when well drained, the land in the northwest quarter of Ohio was cleared more thoroughly than other quarters of the state. It no longer has Wild Turkeys, Ruffed Grouse, Ravens, Passenger Pigeons, Carolina Paroquets, or Pileated Woodpeckers. There are still a few Red-bellied Woodpeckers. They are increasing in Eastern Ohio, Western New York, and near Chicago, probably because of better protection and milder winters.

In Wilson's time there were numerous Ravens, but no Crows, along the south shore of Lake Erie. Their extirpation in Ohio made more room for Crows, just as the later extinction of Passenger Pigeons gave more room for Mourning Doves

In the museum at Bowling Green State University we have a well preserved Pigeon net, about fifty feet long, whose owner succeeded in catching 292 Pigeons at a single throw, thereby beating his father, whose best was an even 24 dozen, or 288 birds. This was probably about 1870.

Paroquets may never have been numerous in Ohio. In 1862 a flock of 25 or more was seen in the Capitol Square of Columbus. A specimen shot near Newark, October 9, 1884, was mounted. When I was teaching at Sandusky in the early 1890's I had a report of a Carolina Paroquet seen six miles south of that city.

Dr. William Graefe collected and had mounted many interesting specimens of birds, which are now preserved in the University Museum at Bowling Green. He told me that in 1880 he shot a Prairie Hen near Sandusky. In Ohio these birds may have lived only in those few counties which had some prairie, most of them in the northwest quarter.

Probably most of the species mentioned above would have disappeared eventually as a consequence of cutting the big timber even if they had not been hunted, but extirpation of most of them was hastened by man's desire to eat their flesh. Even the Pileated Woodpecker, or 'Logcock," was a game bird. About sixty years ago I prepared a skin of one I found at a meat market in Grand Rapids, Michigan. These large Woodpeckers have increased in recent years at some places in eastern Ohio and western Pennsylvania, due probably to better protection.

A century ago there were many Bald Eagles nesting near Lake Erie and Sandusky Bay, probably more than a hundred pairs, each using the same nest year after year, as long as it was safe. Great Horned Owls, Barred Owls, Red-tailed Hawks and Red-shouldered Hawks were also common at that time.

Great Blue Herons are still common, but probably less so than long ago. The largest heronry in Ohio contained 1,118 nests, May 2, 1935; nearly all of them were occupied. This is in Sandusky County nine miles northwest of Fremont. In the Waggoner Woods, where the heronry is now, the birds began to build nests in 1912 and 1913, because the woods three miles nearer to Lake Erie, which had previously harbored them, no longer contained enough large trees. We know that

the older site had been used continuously since about 1840. It may have been used long before that.

Close to the Michigan line, sixteen miles west and north of Toledo, is another old colony of Great Blue Herons, where Reverend Hammond counted 214 nests in 1932. Its present location, in woods of John Ford, has been used only about sixty years. This colony had previously had to change its location more than once. In 1871, year of the great Chicago fire, it was so dry in October that forest fires wrought terrible havoc to both human and avian settlements. Up to that time this heron colony had been using tall cottonwood trees in heavily timbered swamp land about four miles northwest of the Ford woods.

The number of herons in these two old colonies has depended largely on the activities of man, especially in the matter of shooting, for they were able to defend themselves from other predators and had an unfailing food supply in Lake Erie and waters connected with it. Other colonies in Ohio have declined in consequence of the destruction of forests, drainage of the land, and the long succession of dry summers, 1930–41.

Numerous other birds that lived in the forest—Tanagers, Vireos, Thrushes, Ovenbirds, Cerulean Warblers, and others are probably less numerous now.

The drainage of swamps has greatly reduced the habitable areas formerly available for Sandhill Cranes, Rails, Gallinules, Snipes, and a number of land birds which prefer to nest near water—Short-billed Marsh Wrens, Swamp Sparrows, and Yellow Warblers. The clearing away of the bushes on stream banks has decreased the favorite nesting sites of many species.

Telegraph and other wires have caused many bird fatalities, especially in the migrating seasons.

Red-headed Woodpeckers and various other birds have been hit by automobiles. Both game and song birds have been slaughtered by hunters who depended on their cars to take them to the homes of the birds.

The introduction of domestic cats, Sparrows, Starlings and Pheasants has added to the troubles of many native species.

Guns, nets, and traps have exterminated a few kinds of American birds, have reduced almost to the vanishing point several others, and materially decreased the number of many kinds.

In recent years many nests of birds that live in the open fields have been destroyed by mowing machines and by plows and other implements used in fitting the land. Introduction of the alfalfa mill accounts for the earlier mowing of meadows with resulting destruction of numerous nests.

Increase.—On the other hand, many kinds of birds have become more numerous because the activities of man have provided more food for them.

In many of the years since Bowling Green State University started, as a training school for teachers, in 1914, Golden Plover have been seen in large numbers, thousands of them in some years. On their way to their nesting grounds in Arctic America they tarry on the rich land around Bowling Green when it is being plowed for corn. Apparently some flocks remain in one neighborhood for two or three weeks. Many of the birds acquire the summer plumage while they are here. Most of them leave before May 10th. After crossing Lake Erie they probably do not make such a long stop again until they come near the Arctic Ocean. On their way back to enjoy the mild weather prevailing in the southern hemisphere during our northern winter, a few flocks are usually seen somewhere in the Toledo-Bowling Green area.

Until there were orchards, Cape May Warblers could not have found so many

insects during their fall migration. Their marked increase in recent years may be due to the fact that farmers have been too busy to spray their orchards.

We have previously mentioned southern birds which have extended their range northward both because of a milder climate and more food. The increased amount of food has helped also many other birds—Killdeer, Upland Plover, Pectoral Sandpipers, Tree Sparrows, Juncos, and other birds which had always been here for at least part of the year.

Destruction of forests, followed by cultivation of the land, made Indiana and Ohio attractive to birds which had previously lived only on the prairies or plains. A number of plants not found in forests, but common in treeless parts of the West and Southwest, migrated eastward and northeastward after the land was cleared. Some came in baled hay, or in bedding for cattle, others as impurities in seed shipped eastward for planting. Where empty cars which had carried loads of wheat were swept out, unfamiliar weeds sprang up. Many kinds were brought by the wind. Various grasses, sunflowers, and other composites, pigweeds and amaranths, and plants of the mustard and legume families which had been common in the west were brought here in one way or another and added to the food supply of native birds as well as of those whose homes had been where the plants came from.

Examples of birds formerly unknown or merely accidental east of the Illinois prairies are the Dickcissel, Lark Sparrow, Western Henslow's Sparrow, Leconte's Sparrow, Nelson's Sparrow, Western Meadowlark, and Yellow-headed Blackbird. Most of these birds are still uncommon as far east as Ohio, but the Western Henslow's Sparrow nests in considerable numbers at some places in Ohio and Pennsylvania and has increased also in New York State. Prairie Horned Larks have long been common in open places, but until the land was cleared there were none within 300 miles of Toledo. Western Meadowlarks have been observed in larger numbers, 1938–45, in Michigan, and near Indianapolis and Chicago.

Man has also augmented the food supply of birds purposely. He has left, in fence rows and hedges, weeds and shrubs whose seeds or fruit are relished by the birds. He has planted sunflowers and numerous other herbs, shrubs, vines, and trees to provide food for the birds.

Man has aided the birds in other ways. Shelters of plant growth on the borders of fields, nesting boxes, feeding shelves, drinking and bathing places have added to their safety and comfort. Putting out food for them has enabled many to survive in bad weather.

Many kinds of birds are safer when living near man. He no longer confines them to cages to hear them sing. In this country, except in lawless communities, he does not shoot song birds for food or because he has no other living creatures to shoot at.

This changed attitude toward birds has come about mainly in recent decades. Much credit for it is due the Audubon Societies and other associations for the protection of birds. Probably even more has been done by the schools, many of them aided by natural history museums. They have succeeded in getting the children interested in finding out more about the life of birds and in that way becoming more sympathetic toward them.

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LABORATORY TESTS SHOWING THE EFFECT OF DDT ON SEVERAL IMPORTANT PARASITIC INSECTS

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During the summer of 1945 the author was given the opportunity to study the effect of DDT, a new touch insecticide, on certain parasitic insects, particularly those attacking the oriental fruit moth (*Grapholitha molesta* (Busck)) and the strawberry leaf roller (*Ancylis comptana fragariae* (Walsh and Riley)). The project was a cooperative set-up between the U. S. Bureau of Entomology and Plant Quarantine and the Department of Entomology of the Ohio Agricultural Experiment Station at Wooster, Ohio. The author is indebted to N. D. Blackburn for assistance in obtaining some of the parasites and for observations made when the author was absent, to H. W. Allen of Moorestown, N. J., for shipments of living specimens of *Macrocentrus ancylivorus* Roh. and to C. F. W. Muesebeck for final determination of the species of parasitic insects tested.

The following is a brief summary of the many tests conducted in the laboratory to determine how toxic a dry deposit of DDT spray on foliage might be to parasitic adult insects that visited the treated leaves. The tests were designed to determine the strength of DDT and the exposure time required to kill, as well as the toxicity of deposits one to nine weeks old on orchard-sprayed foliage. The exploratory nature of the project gave the writer an opportunity to test various parasitic and predacious insects, however, this report is restricted to a summary of the results obtained from numerous tests with five parasitic species, namely, one braconid, *Macrocentrus ancylivorus* Roh., an important parasite of the Oriental fruit moth, reared from field-collected strawberry leaf rollers and from the potato tuber worm, (*Gnorinioschema operculella* (Bell)), in the laboratory; two ichneumonids, *Cremastus cookii* Weed and *C. forbesi* Weed reared from field-collected strawberry leaf rollers, and two tachinids, *Nemorilla florialis* (Fall.) reared from field-collected strawberry leaf rollers and *Archytas apicifera* (Walk.) collected on sweet clover.

The DDT (2, 2-bis (p.-chlorophenyl)-1, 1, 1-trichloroethane) used was prepared by du Pont under the trade name "Deenate, 25W." This wettable powder contained 25 per cent DDT. Consequently in all the formulae employed, 4 parts were used for each single unit of DDT stated in the dosages named. Three methods of testing were employed, namely, small vials for walk-tests, large vial tests, and small wood-gauze-celluloid cage (4" x 4" x 6") tests. The cage tests were most satisfactory; hence, most of the results reported are from exposures made in the cages.

SMALL-VIAL TESTS.—For testing parasites individually, especially for short exposures not exceeding 10 seconds, the small-vial walk-testing prodecure was very satisfactory. In this method a single adult was placed in a clean 15 x 80 mm. shall vial. The open end of the vial was inserted in a glass tube 15 cm. long lined in the center with 5 cm. of sprayed (dry) peach foliage. By proper orientation toward a light source (a north window) the adult was induced to walk over the sprayed foliage and into a clean 15 x 80 mm. shell vial at the opposite end. This contained a small drop of honey-agar. After the adult had entered, the vial was removed and stoppered with a moistened gauze covered cotton plug. The act of walking over the sprayed foliage required 2 to 10 seconds. When tested individually in lots of 10 replicated several times, the results with adults of *M. ancy-*

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livorus showed 60 to 90 per cent kill within 36 hours after the adults had walked over and touched a dry deposit of DDT on a peach leaf that had been sprayed with a 1-1000 water suspension of the material (i.e., 1 gram of DDT in 1000 cc. of water). In similar tests *Cremastus cookii*, *C. forbesi* and *Nemorilla floralis* were unaffected by the same spray, also sprays containing 1 part of DDT to 5000 and 10,000 parts water produced no kill.

LARGE-VIAL TESTS.—Numerous large-vial (1″ x 8″) tests were conducted with the various parasites. The results in most cases were very similar to the small cage tests; consequently, they will not be reviewed in this report. One or two facts, however, should be mentioned. A 10-minute exposure of *M. ancylivrous* to DDT sprayed at the rate of 1-1000 killed all the adults, while 10 minutes exposure to DDT at the rate of 1-5000 to 1-10,000 produced only 60 to 70 per cent kill. In general, the percentage killed in the large vials was not as high for a given exposure or dosage as similar tests in the cages. This may have been due to the high humidity present in the vials, especially where leaves were present for the duration of the test.

CAGE TESTS.—The cages used were 4″ x 4″ x 6″. The ends, top and bottom were made of wood; the back was covered with gauze, and on the front was a sliding door made of wood and celluloid. These cages resembled closely the shipping container described previously (Peterson, 1934). The principal differences were that one long side of the cage served as a bottom, the sliding door was covered with celluloid, the 2 dram homeopathic vial containing water and dental cotton was fastened in a horizontal position to the inner surface of the left end, and the piece of cardboard smeared with a honey-agar mixture was tacked to the rear inner surface of the top board. In each cage either a sprayed or an unsprayed peach twig possessing five to seven leaves and held in a 3-dram homeopathic, cotton-stoppered, water-filled vial was inserted in such a manner that some of the leaves were in contact with the gauze side of the cage which faced the outside light source. All cages were cleaned thoroughly and swabbed with 95 per cent ethyl alcohol before they were used for succeeding tests. In each cage was placed fresh water, honey-agar food, and the test peach twig, before the 10 to 25 or more adults were introduced through the cork-stoppered opening. The twig was kept in the cage for the duration of the test. In most tests more females than males were used when it was possible to determine the sexes readily. All cages were placed on the wide sill of a north window which was kept open day and hight. The temperatures within the cages agreed closely with those recorded at the Ohio Agricultural Experiment Station weather station. Usually final records were taken 36 to 48 hours after the adults were introduced. In most tests the mortality in the check cages was less than 10 per cent. If the mortality in the check cages exceeded 25 per cent, the series was considered unsatisfactory. The cages were used primarily for two types of testing, namely, (a) the determination of the dosage of DDT required to kill and (b) the effect on the toxicity of DDT-spray deposited on the foliage of peach trees which remained exposed to the weather in the orchard until used.

In the dosage tests, 10 to 25 (or more) adults, usually less than 3 days old, were used in each cage. The number employed depended upon the supply available. Two series of dosages were employed: (a) If the supply of parasites was large, dosages of DDT at the rate of 1-10,000, 1-20,000, 1-30,000, 1-40,000, 1-50,000 and 1-100,000 water suspensions were used. (b) When the parasite supply was low, dosages of 1-10,000, 1-50,000 and 1-100,000 were used. In all the tests, the peach foliage was sprayed at the specified dosages and allowed to dry thoroughly before the twigs were placed in the cages. All five species of insect parasites named previously were subjected to the dosage tests. In most cases, especially among the species of Hymenoptera, all tests were replicated several times.

RESULTS OF DOSAGE TESTS.—In all of the experiments with all five species of parasites, a dosage of DDT at the rate of 1-10,000 killed 100 per cent, except in one replication with *C. forbesi* where 90 per cent were killed. In a number of series of tests, dosages as low as 1-50,000 killed 100 per cent, especially in tests with *M. ancylivorus* and *A. apicifera*. Also, in some of the tests with *M. ancylivorus*, 60 per cent of the adults were killed at a dosage of 1-100,000. Among the Hymenoptera, *M. ancylivorus* proved to be somewhat more susceptible to DDT than the species of *Cremastus* tested. This was most evident at dosages more dilute than 1-30,000. It was observed among the Hymenoptera that males and females were equally susceptible to DDT.

The age of the DDT deposit on foliage appeared to effect the toxicity of the material. This was indicated strongly in some of the series A dosage tests where sprayed leaves of a given test were held for 3 to 5 days and used again in the same cages with the same species of parasite. In the repeat tests with *M. ancylivorus* and *C. forbesi* the percentages of kill were lower at all dosages less than 1-20,000 than in the first tests with the same sprayed leaves. This indicates strongly that some deterioration in the toxicity of the DDT on the sprayed leaves took place during the 3 to 5 day holding period.

TABLE I

TABLE SHOWING THE EFFECT OF AGE-OF-SPRAY-DEPOSIT ON THE TOXICITY OF DDT TO *M. ancylivorus*

Dosage 1 part DDT to 1000 parts of water

Cage	Date Sprayed	Tested 7/31, 70–95° F., 50 per Cage				Tested 8/22, 61–74° F., 25 per Cage			
		Age in Days of Deposit	Inches of Rain*	No. Dead 35 Hr.	Pct. Dead	Age in Days of Deposit	Inches of Rain*	No. Dead 40 Hr.	Pct. Dead
A	Check	No DDT	3.80 (12)	10	20	No DDT	5.17 (16)	3	12
B	6/19	42	3.80 (12)	6	12	64	5.17 (16)	12	48
C	6/25	36	3.63 (11)	43	86	58	5.00 (15)	23	92
D	7/2	29	2.81 (9)	49	98	51	4.08 (12)	25	100
E	7/9	22	2.66 (7)	43	86	44	3.93 (11)	25	100
F	7/16	15	.38 (4)	50	100	43	1.65 (8)	25	100
G	7/23	8	.05 (2)	50	100	30	1.32 (6)	25	100
H	7/30					23	1.29 (5)	25	100
I	8/6					16	1.27 (4)	25	100

*The numbers in parentheses indicate the number of rains the checks and treated foliage received.

An interesting observation relating to temperature was noted in the dosage tests and also in the tests with deposits of various ages on orchard-sprayed foliage (see table). In several tests with *M. ancylivorus* and *C. forbesi*, it was observed that more rapid and more extensive kill took place when the temperatures during the cage tests averaged close to 70° F. than in similar tests where the average temperature of the cages was 80° F. and higher. Further tests are needed to substantiate these unexpected results.

RESULT OF AGE-OF-DEPOSIT-TESTS.—In addition to the dosage and exposure time experiments, a series of tests with foliage sprayed at 7-day periods from June 19 to August 8 were conducted on July 2, 11, 16, 23. 30, and August 8 and 22, 1945. In these tests the adult parasites were exposed to the foliage from the orchard-sprayed trees coated once with DDT at the rate of a 1-1000 water suspension. During the season, *M. ancylivorus* was available for all the test periods;

adults of other parasites, reared from the strawberry leaf roller, were available to July 20; and *A. apicifera*, collected from sweet clover, from July 30 to August 10.

In all of the age tests where average temperature during the test period did not exceed 72° F., 100 per cent of all of the adults of all the species were killed when exposed to DDT orchard-sprayed foliage 1 to 4 weeks old. In similar tests with *M. ancylivorus*, 100 per cent kill took place with orchard-sprayed foliage 7 weeks old. If the temperature at the test period averaged 80° F. or higher, the percentage killed was reduced somewhat. Rainfall on the sprayed foliage apparently did not reduce sufficiently the toxicity of DDT to parasites to permit them to visit the treated foliage without some or complete mortality.

Individual peach trees were sprayed once with DDT at the rate of 1-1000 on the dates indicated. These trees received no further sprays or dusts during the entire season. The table shows the age of the sprayed foliage employed, the rains to which it was subjected, and the number and percentage of adults killed in two of the tests. Note that lower percentages of kill are recorded when the test was made at temperatures averaging 82° F. (July 31 test) than at temperatures averaging 68° F. (August 22 test).

SUMMARY

Tests were conducted on the effect of DDT on certain parasitic insects, particularly those attacking the oriental fruit moth (*Grapholitha molesta* Busck)) and the strawberry leaf roller (*Ancylis comptana fragariae* (Walsh & Riley)), to determine the strength of DDT and the exposure time required to kill and the toxicity of deposits 1 to 9 weeks old on orchard-sprayed foliage.

DDT was found to be exceedingly toxic to *Macrocentrus ancylivorus* Roh., *Cremastus cookii* Weed, *Cremastus forbesi* Weed, *Nemorilla floralis* (Fall.), and *Archytas apicifera* (Walk.).

In all tests except one, 1 part of DDT to 10,000 parts of water killed 100 per cent of the adults of all five species. *Macrocentrus ancylivorus* and *Archytas apicifera* showed total mortality at strengths as low as 1 part to 50,000.

DDT on peach foliage from the orchard sprayed at the rate of 1 part to 1,000 parts of water continued to be highly toxic for 4 to 7 weeks. In some tests with *Macrocentrus ancylivorus* 100 per cent kill resulted when males and females were exposed to orchard-sprayed peach foliage at least 7 weeks after a single spraying with DDT.

CONCLUSIONS

The above laboratory tests indicate that DDT may prove to be toxic to adults of many species of braconids, ichneumonids and tachinids if they touch, walk or rest on plants in the field that have been sprayed with DDT for the control of insect pests. Briefly stated, biological control of some insects may be curtailed when DDT is used extensively.

LITERATURE CITED

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THE LIFTING EFFECT OF QUICKSAND

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Two extremes of opinion regarding the lifting effect of quicksand may be briefly stated. One of these, in fact, the opposite of lifting effect, is exemplified by the general picture of quicksand deposits as lying in wait to entrap and engulf the unwary. This is the quicksand, not only of novels such as *Lorna Doone*, *Moonstone* and *Assignment in Brittany*, but also it is a very common belief. Certainly, each year, quicksand is the cause of loss of considerable numbers of domestic animals, of human lives and of considerable property. The other opinion was stated in 1931 in an article in *Science News Letter* (3) as follows: "You're Safe in Quicksand If

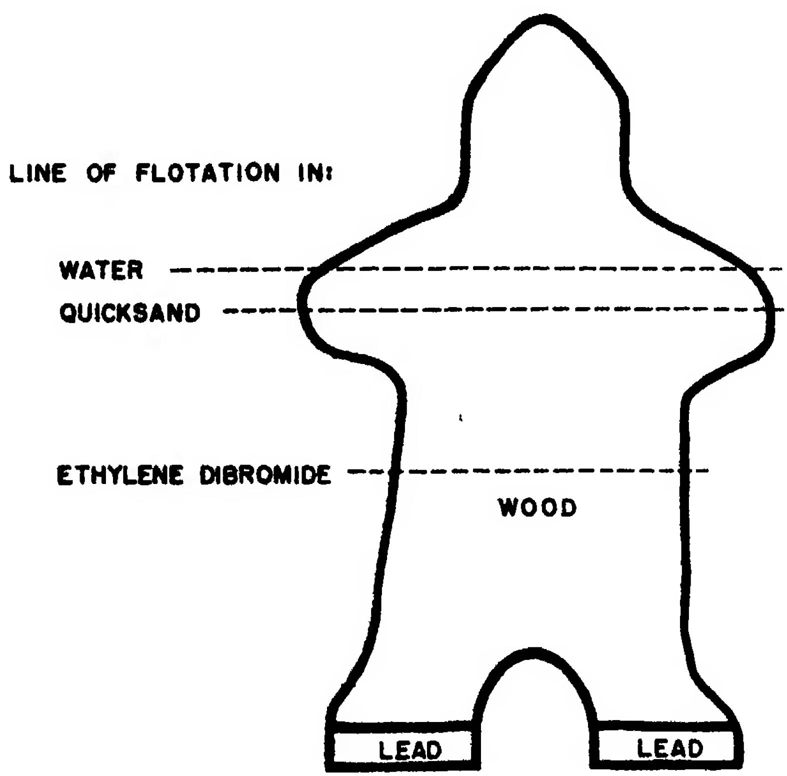

FIG. 1. Comparison of Buoyancy of Water and Ethylene Dibromide with Lifting Effect of Quicksand.

You Keep Still. . . . If you ever have the misfortune to fall into quicksand, don't get panicky and thrash around. If you keep quiet, allow yourself to go down feet first and keep your arms outstretched, you will soon find yourself resting at a depth just below your armpits. As a matter of fact, quicksand will support you twice as easily as water."

In view of the theory of what makes quicksand "quick," as proposed in 1900 by Hazen (2), later by Burt (1) and at somewhat greater length by the present writer

in 1945 (4), it was decided to test exactly the lifting power of a given quicksand. This theory, in brief, is that quicksand has its particular properties because water (a spring) is rising through it with sufficient velocity to lift the sand grains apart; thus the immersed body is going down into water, handicapped by the sand and under the lifting effect of the buoyancy of the water as well as the rising current. To study exactly this lifting effect, a model of wood (*Liriodendron*) (Fig. 1) was made, with strips of lead fastened on the feet to keep the model upright in liquids.

The levels to which it sank in water and in sand made quick by rising currents were marked on the model. (Fig. 1.) The lifting power of the particular quicksand used was then determined by use of an hydrometer to be equal to that of a liquid with a specific gravity of 1.156. This is between one-sixth and one-seventh greater than that of water. The exact level will be determined by two factors: (a) the specific gravity of the entrapped body (a man with hunting boots and a cartridge belt or a man who when swimming has difficulty floating and can easily sit down on the bottom of a swimming pool may be entirely engulfed); and (b) the velocity of the rising current. It is this second factor which leads the writer to use the term, "lifting effect," rather than buoyancy, buoyancy being only part of the "picture." The necessary velocity of the rising current will be determined by the weight of the individual grains of sand, the coarser and heavier the grain, the greater the velocity and the greater the lifting effect of the quicksand.

The lifting effect corresponding to that of a liquid with a specific gravity of 1.156 does not agree with the statement in the *Science News Letter*, ". . . . quicksand will support you twice as easily as water." To check just how high a liquid with twice the buoyancy of water would lift the model, it was put in ethylene dibromide, specific gravity of 1.96. Figure 1 shows that this liquid, with a specific gravity of nearly two, lifts the model very much higher than quicksand. Thus quicksand has a lifting effect, not twice that of water, but about one and one-seventh times that of water.

REFERENCES

(1) **Burt, F. A.** 1927. Genesis of Quicksand Deposits. *Pan. Am. Geol.*, 47: 226.
(2) **Hazen, A.** 1900. Discussion of Quicksand. *Trans. Amer. Soc. Civ. Engrs.*, 43: 582.
(3) *Science News Letter*. 1941. You're Safe in Quicksand if You Keep Still. 39: 282.
(4) **Smith, Ernest Rice.** 1946. Sand. *Proc. Indiana Acad. Sci.*, 55 (In press).

CHECK LIST OF OHIO LEAFHOPPERS
(HOMOPTERA: CICADELLIDAE)

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An attempt is made to list all species known to occur in Ohio. This list is based on three papers dealing especially with Ohio fauna: Osborn, Herbert, Ohio Biological Survey Bulletin 14, 1928, and Supplemental Records and Notes on Ohio Leafhoppers, *Ohio Journal of Science*, 32: 513–517, 1932; and Johnson, Dorothy M., Ohio Biological Survey Bulletin 31, 1935.

Since the publication of these papers a large number of additional species has been collected, and numerous changes, particularly in generic placement, have been made. In case the genus differs from that under which the species was listed in these papers, the old generic name follows the specific name in parentheseses and is italicized. The same treatment is used for synonymy and for varieties which have been raised to specific rank. All species which are additions are in bold face type and an asterisk is placed in front of the name. These new records may be from publications by various authors in which the species are described, or from material collected or determined more recently. The determinations have been made by D. J. Knull and all records, unless other collectors are mentioned, are from the collecting of D. J. & J. N. Knull.

A total of 615 species and 32 varieties of which 171 species and 11 varieties are new records are listed.

EURYMELINAE Kirkaldy
  Idiocerus Lewis
    alternatus Fitch
    ***amabilis** Ball, Ashtabula Co., June 24, 1931, E. P. Breakey; Sugar Grove, July 27, 1928, C. C. B. Mayer; Hocking Co., July 27, 1944.
    crataegi V. D.
    duzeei Prov.
    fitchi V. D.
    ***formosus** Ball, Hocking Co., June 19, 1938.
    lachrymalis Fitch
    nervatus V. D.
    pallidus Fitch
    provancheri V. D.
    scurra (Germar)
    snowi Gillette & Baker
    ***subnitens** Sanders & DeLong, Ashtabula Co., June 24, 1931, E. P. Breakey.
    suturalis Fitch
      var. **lunaris** Ball

MACROPSINAE Evans
    basalis (Van Duzee)
    bicolor (Osborn)
    cinerea Breakey
    ***confusa** Breakey
    erythrocephala (G. & B.)
    ferruginoides (V. D.)
    ***fumipennis** (G. & B.), Delaware Co., June, 1944—(*crocea* (O. & B.))
    gleditschiae (O. & B.)
    insignis (V. D.)
    nigricans V. D.
    osborni Breakey
    ***quadrimaculata** Breakey, Hocking Co., Sept. 14, 1944.
    reversalis (O. & B.)
    ***robusta** Breakey, Lucas Co., June 21, 1943.
    rufocephala Osborn
    sordida (V. D.)
    suturalis (O. & B.)
    trimaculata (Fitch)
    tristis (V. D.)
    trivialis (Ball)
    ***virescens** (Gmelin)
      var. **graminea** (Fabr.)
    viridis (Fitch)
  Oncopsis Burmeister
    cognatus (V. D.)
    ***fagi** (Fitch), common
    fitchi V. D.
    minor (Fitch)
    nigrinasi (Fitch)
    ***sobrius** (Walker)
    variabilis (Fitch)
    verticis (Say)—(*distinctus* (V. D.))
  Nionia Ball
    palmeri (V. D.)

AGALLIINAE Kirkaldy
Agalliopsis Kirkaldy
*__cervina__ Oman, Hocking Co., June 16, 1945.
novella (Say)—(*Agallia*)
*__peneoculata__ Oman—(*Agallia oculata* V. D.), Little Mt., Aug. 24, 1904, J. G. Sanders, Williams Co., E. P. Breakey.
Agallia Curtis
constricta V. D.
quadripunctata (Prov.)
Aceratagallia Kirkaldy
sanguinolenta (Prov.)—(*Agallia*)

BYTHOSCOPINAE Dohrn
Stragania Stål
(Penestragania) Beamer & Lawson
*__alabamensis__ (Baker), Columbus, June 29, 1942.
apicalis (O. & B.)—(*Bythoscopus*)

TETTIGONIELLIDAE Jacobi
Aulacizes
irrorata (Fabricius)
Cuerna Melichar
lateralis (Fabricius)—(*Oncometopia*)
*__limbata__ (Say)
Oncometopia Stål
undata (Fabricius)
Ciminius Metcalf & Bruner
hartii (Ball)—(*Kolla*)
Kolla Distant
bifida (Say)
geometrica (Signoret)
Helochara Fitch
communis Fitch
Graphocephala V. D.
coccinea (Forster)
versuta (Say)
Plesiommata Provancher
tripunctata (Fitch)—(*Pagaronia*)
Draeculacephala Ball
anguilifera (Walker)
*__antica__ (Walker)
*__constricta__ Davidson & DeLong
inscripta V. D.
minor (Walker)
mollipes (Say)
prasina (Walker)—(*noveboracensis* (Fitch))
Neokolla Melichar
gothica (Signoret)—(*Cicadella*)

EVACANTHINAE Baker
Evacanthus LaPeletier & Serville
acuminatus (Fabricius)

GYPONINAE Stål
Penthimia Germar
americana Fitch
Gypona Germar
melonata Spångberg
Gyponana Ball
*__acia__ DeLong, Columbus, June 20, 1945; Delaware Co., July 16; Hocking Co., July 26, 1945.
*__amara__ DeLong
*__arcta__ DeLong, on hemlock, Fairfield Co., July 10, 1945; Hocking Co., July 2, 1945.
*__brevihama__ DeLong
*__cacumina__ DeLong
*__conferta__ DeLong
*__contractura__ DeLong
*__expanda__ DeLong
*__extenda__ DeLong
*__flavilineata__ (Fitch)
*__gladia__ DeLong, Hocking Co., June 10, July 2, 1945.
*__lamina__ DeLong
*__mali__ DeLong
*__morosita__ DeLong
octolineata (Say)—(*Gypona*)
*var. **serpenta** DeLong, Fairfield Co., June 10, 1945.
*__ortha__ DeLong, common
*__palma__ DeLong
*__panda__ DeLong
*__pingua__ DeLong
*__protenta__ DeLong
*__salsa__ DeLong
*__scrupulosa__ (Spångberg)
*__serrata__ DeLong
striata (Burm.)
*__tenella__ (Spångberg)
*__trigona__ DeLong, Hocking Co., August 29. 1943.
*__tubera__ DeLong
*__turbina__ DeLong
unicolor (Stål)—(*Gypona*)
*__vasta__ DeLong
Rugosana DeLong
*__querci__ DeLong—(*Gypona rugosa* Spångberg)
Ponana Ball
*__aenea__ DeLong
limbatipennis (Spångberg)—(*scarlatina* var.)
limonea Ball & Reeves (*scarlatina* var.)
pectoralis (Spångberg)—(*scarlatina* var.)
puncticollis (Spångberg)
*__quadralaba__ DeLong
*__rubida__ DeLong
scarlatina (Fitch)—(*rodora* Ball)

LEDRINAE (Stål)
Xerophloea Germar
majesta Lawson
major Baker
viridis (Fabricius)

DORYDIINAE V. D.
Parabolocratus Fieber
flavidus Signoret
major Osborn
*__rotundus__ DeLong
viridis (Uhler)
APHRODINAE Kirk.
Aphrodes Curtis
albifrons (Linn.)—(*Acucephalus*)
bicinctus (Schrank)—(*Acucephalus nervosus* (Schrank))
flavostrigatus (Donovan)—(*Acucephalus flavostriatus*)
Xestocephalus V. D.
brunneus V. D.
coronatus O. & B.
nigrifrons Osborn
piceus Osborn

*__provancheri__ Knull
__pulicarius__ V. D.
*__similis__ Peters, Columbus, August, 1944; Delaware Co., August 9 and 24, 1944.
__superbus__ (Prov.)
__tessellatus__ Van Duzee

ATHYSANINAE Van Duzee
__Sanctanus__ Ball
__sanctus__ (Say)—(*Scaphoideus*)
__Scaphoideus__ Uhler
*__auctus__ DeLong & Mohr, Put-in-Bay, July 5, 1935, J. N. Knull.
*__baculus__ DeLong & Mohr, Columbus, July 14 and 22, 1934, Whittington, (A. C. Miller Collection).
*__bifurcatus__ DeLong & Mohr, Hocking Co., July 26, August 16, 1945; Fairfield Co., July 26, 1945.
__carinatus__ Osborn
*__chelus__ DeLong and Beery, Fairfield Co., July 26; Hocking Co., July 2.
__cinerosus__ Osborn
*__cylindratus__ DeLong & Beery, Hocking Co., June 20 and July 26, 1945.
*__densus__ DeLong & Beery, Little Mt., August 21, 1904 (Osborn collection), paratype.
*__dilatus__ DeLong & Mohr, Delaware Co., August 2, 1945.
*__frisoni__ DeLong & Mohr, Fairfield Co., June 16, 1945.
__immistus__ (Say)
__incisus__ Osborn, common
__flexus__ DeLong & Mohr, new synonymy
*__littoralis__ Ball, Columbus, July 27, 1944.
__luteolus__ V. D.
__major__ Osborn
__melanotus__ Osborn
__minor__ Osborn
*__nigrellus__ DeLong & Mohr, Morrow Co., August 20, 1938, E. S. Thomas; Delaware Co., August 22, 1945; Medina Co., August 28, 1945.
__nigricans__ Osborn
__obtusus__ Osborn, Delaware Co., July 2 and 4, 1944; Hocking Co., July 10, 1945.
__ochraceous__ Osborn
__opalinus__ Osborn
__productus__ Osborn
*__pullus__ DeLong & Mohr, Hocking Co., July 10, 1945; Pickaway Co., June 22, 1945.
*__scelestus__ DeLong & Mohr, Hocking Co., August 1, 1944; Franklin Co., July 14, 1942.
*__tergatus__ DeLong, Morrow Co., August 20, 1938, E. S. Thomas; Champaign Co., July 29, 1934, F. Whitington (A. C. Miller Collection); Delaware Co., Aug., Sept., 1944–45; Fairfield Co., July 26, 1945.
*__transeus__ DeLong & Beery, Hocking Co., July 2.
*__veterator__ DeLong & Beery, Fairfield Co., August 15, 1945.
__Lonenus__ DeLong
__intricatus__ (Uhler)—(*Scaphoideus*)
__Osbornellus__ Ball
*__alatus__ Beamer, Hocking and Fairfield Counties.
__auronitens__ (Prov.)—(*Scaphoideus*)
*__clarus__ Beamer, Monroe Co., July 6, 1943.
__consors__ (Uhler)—(*Scaphoideus*)
*__corniger__ Beamer, Columbus, July 27, 1944; Delaware Co., August 24, 1944.
__jucundus__ (Uhler)—(*Scaphoideus*)
*__limosus__ DeLong, Hocking Co., August 1, 1944; September 3, 1943.
*__radix__ DeLong & Mohr, Columbus, July 28, 1928, C. C. B. Mayer.
*__rotundus__ Beamer
__scalaris__ (V. D.)—(*Scaphoideus*)
__unicolor__ Osborn—(*Scaphoideus*)
__Prescottia__ Ball
__lobata__ (V. D.)—(*Scaphoideus*)
__Platymetopius__ Burmeister
__vitellina__ (Fitch)—(*Platymetopius*)
__Japanus__ Ball
__hyalinus__ (Osborn)—(*Platymetopius*)
__Scaphytopius__ (*Cloanthanus*) Ball
__acutus__ (Say)—(*Platymetopius*)
*__angustatus__ (Osborn), Hocking Co., October 17, 1944, det. Hepner.
*__argutus__ (DeLong), Ashtabula Co., June 24, 1931, C. C. B. Mayer, det. Hepner.
*__bicolor__ (DeLong), Hocking Co., September 16, 1943; Fairfield Co., June 16, 1945.
__cinereus__ (O. & B.)—(*Platymetopius*)
__cuprescens__ (Osborn)—(*Platymetopius*)
__frontalis__ (V. D.)—(*Platymetopius*)
__fulvus__ (Osborn)—(*Platymetopius*)
*__hastus__ DeLong, Hocking Co., June, July, August, October; Scioto Co., June 10, 17.
*__latus__ (Baker)
__magdalensis__ (Prov.)—(*Platymetopius*)
*__nigrifrons__ (DeLong), Delaware Co., June July, Hocking Co., July, September.
*__obscurus__ (Osborn)—(*Platymetopius*)
*__scriptus__ (Ball), Delaware Co., June, July, August, September; Cedar Swamp, September 5, 1941; Champaign Co., July 29, 1934, F. Whittington (A. C. Miller Collection).
*__triangularis__ DeLong, Delaware Co., June, July, September; Hocking Co., June, September 14, 1944; Scioto Co., June 10, 17.
__Acurhinus__ Osborn
__pyrops__ (Crumb)
__Flexamia__ DeLong
__abbreviata__ (O. & B.)—(*Deltocephalus*)
__areolata__ (DeLong)—(*Deltocephalus*)
*__atlantica__ (DeLong)
__imputans__ (O. & B.)—(*Deltocephalus*)
__inflata__ (O. & B.)—(*Deltocephalus*)
__picta__ (Osborn)—(*Deltocephalus*)
__reflexa__ (O. & B.)—(*Deltocephalus*)
__sandersi__ (Osborn)—(*Deltocephalus*)
*__stylata__ (Ball)
__Latalus__ DeLong & Sleesman
__configuratus__ (Uhler)—(*Deltocephalus*)
__sayi__ (Fitch)—(*Deltocephalus*)
__Palus__ DeLong & Sleesman
__delector__ (S. & D.)—(*Deltocephalus*)
__Polyamia__ DeLong
__apicata__ (Osborn)—(*Deltocephalus*)
__compacta__ (O. & B.)—(*Deltocephalus*)

inimica (Say)—(*Deltocephalus*)
interrupta (DeLong)—(*Deltocephalus*)
obtecta (O. & B.)—(*Deltocephalus*)
weedi (V. D.)—(*Deltocephalus*)
Laevicephalus DeLong
*__acus__ (S. & DeL.), Scioto Co., June 10, 17, 1944; Hocking Co., September 16, 1943.
debilis (Uhler)—(*Deltocephalus*)
melsheimerii (Fitch)—(*Deltocephalus*)
minimus (O. & B.)—(*Deltocephalus*)
*__parvulus__ (Gill.), Scioto Co., June 1, 1945.
*__spicatus__ (DeLong), Scioto Co., June 10, 17, 1944; Hocking Co., June 3, 1943.
striatus (L.)—(*Deltocephalus*)
sylvestris (O. & B.)—(*Deltocephalus*)
*__uhleri__ Oman
unicoloratus (O. & B.)—(*Deltocephalus*)
Amplicephalus DeLong
osborni (Van Duzee)—(*Deltocephalus*)
simplarius (O. & B.)—(*Deltocephalus simplex* V. D.)
Deltocephalus Burmeister
balli V. D.
caperatus Ball
flavicostus (Stål)
*__pulicarius__ (Fallén)
Unerus DeLong
*__colonus__ (Uhler), Hocking Co., September 9, 1939.
Lonatura O. & B.
catalina O. & B.
Amblysellus Sleesman
curtisii (Fitch)—(*Euscelis*)
Amphipyga Osborn
balli Osborn
Driotura Osborn & Ball
gammaroides (V. D.)
*var. **flava** O. & B., Cantwell Cliffs, August 11, 1934, Whittington (A. C. Miller Collection).
*var. **fulva** O. & B., Hocking Co., August 5, 1945, Whittington (A. C. Miller Collection).
Doratura Sahlberg
*__stylata__ (Bohemann), Oak Openings, Lucas Co., July 20, 1943.
Exitianus Ball
obscurinervis (Stål)—(*Euscelis*)
Limotettix Sahlberg
parallelus (V. D.)—(*Euscelis*)
striolus (Fallén)—(*Euscelis*)
Euscelis Brullé
extrusus (V. D.)
sahlbergi (Reuter)—(*deceptus* S. & DeLong)
Ophiola Edwards
anthracina (V. D.)—(*Euscelis*)
cornicula (Marsh)—(*Euscelis plutonius* Uhler)
cuneata (S. & DeL.)—(*Euscelis*)
*__osborni__ Ball, Scioto Co., June 17, 1944.
striatula (Fallén)—(*Euscelis*)
uhleri (Ball)—(*Euscelis*)
Stirellus O. & B.
bicolor V. D.
*__convexus__ Thomas
*__obtutus__ V. D., Adams Co., October 12, J. S. Caldwell.
Aligia Ball
*__modesta__ (O. & B.), Delaware Co., August 2, 9, 1945; Fairfield Co., July 10, 1945.
Mesamia Ball
nigridorsum Ball
*__straminea__ (Osborn)
Bandara Ball
aurata (Ball)—(*Eutettix*)
*__curvata__ Knull
*__inflata__ Knull
johnsoni (V. D.)—(*Eutettix*)
*__parallela__ Knull
Opsius Fieber
stactogalus Fieber—(*Eutettix*), common on larch.
Eutettix Van Duzee
*__brunneus__ Osborn, Delaware, Hocking, Fairfield, Licking and Medina Cos., *Carpinus*.
luridus (V. D.)
marmoratus V. D.
querci G. & B.
southwicki V. D.
subaenus (V. D.)
Norvellina Ball
chenopodii (Osborn)—(*Eutettix*)
helenae Ball
*__pulchella__ (Baker), Athens, June 25, 1932, W. C. Stehr.
seminuda (Say)—(*Eutettix*)
Menosoma Ball
cincta (O. & B.)—(*Eutettix*)
Orientus DeLong
*__ishidae__ (Mats.), Bexley, Columbus
Iowanus Ball
*__borrori__ (DeLong)
majestus (O. & B.)—(*Phlepsius*)
Texananus Ball
decorus (O. & B.)—(*Phlepsius*)
rufusculus (O. & L.)—(*Phlepsius*)
spatulatus (V. D.)—(*Phlepsius*)
Paraphlepsius Baker
apertus (Van Duzee)—(*Phlepsius*)
brunneus (DeLong)—(*Phlepsius*)
cinereus (V. D.)—(*Phlepsius*)
collitus (Ball)—(*Phlepsius*)
*__eburneolus__ (O. & L.)—(*Phlepsius*)
fulvidorsum (Fitch)—(*Phlepsius*)
fuscipennis (V. D.)—(*Phlepsius*)
var. **turpiculus** (Ball)—(*Phlepsius turpiculus*)
incisus (V. D.)—(*Phlepsius*)
irroratus (Say)—(*Phlepsius*)
maculosus (Osborn)—(*Phlepsius*)
punctiscriptus (V. D.)—(*Phlepsius*)
pusillus (Baker)—(*Phlepsius*)
ramosus Baker
*__slossonae__ (Ball)—(*Phlepsius*)
solidaginis (Walker)—*Phlepsius nebulosus* V. D.)
strobi (Fitch)—(*Phlepsius uhleri* V. D.)
tenessus (DeLong)—(*Phlepsius*)
tigrinus (Ball)—(*Phlepsius*)
truncatus (V. D.)—(*Phlepsius*)
tullahomi (DeLong)—(*Phlepsius*)
Fieberiella Signoret
*__florii__ (Stål), Columbus, July, 1944, at light.

Acinopterus V. D.
acuminatus V. D.
Idiodonus Ball
kennicotti (Uhler)—(*Thamnotettix*)
Colladonus Ball
clitellarius (Say)—(*Thamnotettix*)
*var. **marcidus** Ball
Colladonus Ball
collaris (Ball)—(*Thamnotettix*)
furculatus (Osborn)—(*Thamnotettix*)
Doleranus Ball
longulus (O. & B.)—(*Thamnotettix*)
vividus (Crumb.)—*Chlorotettix*)
Atanus Oman
***perspicillatus** (O. & B.), Athens, September 2, 1938, W. C. Stehr; Columbus, July, August, 1944, at light.
Thamnotettix Zetterstedt
simplex H. S.—(*Chlamydatus* (Prov.))
Cicadula Zetterstedt
melanogaster (Prov.)—(*Thamnotettix*)
cyperacea (Osborn)—(*Thamnotettix*)
Elymana DeLong
inornata (V. D.)—(*Thamnotettix*)
Graminella DeLong
fitchi (V. D.)—(*Thamnotettix*)
nigrifrons (Forbes)—(*Thamnotettix*)
pallidula (Osborn)—(*Thamnotettix*)
Chlorotettix V. D.
***attenuatus** Brown
balli Osborn
galbanatus V. D.
***iridescens** DeLong
lusorius (O. & B.)
spatulatus Osborn & Ball
tergatus (Fitch)
***tunicatus** Ball, Hocking Co., June 26, 1944, September 14, 1944.
unicolor (Fitch)
***vacunus** (Crumb), Hocking Co., September 16, 1943.
viridius Van Duzee
Davisonia Dorst
***delongi** Dorst
***major** Dorst
punctifrons (Fallén)—(*Cicadula*)
var. **repleta** (Fieber)—(*Cicadula*)
Macrosteles Fieber
divisa (Uhler)—*Cicadula sexnotata* (Fallén)
lepida (V. D.)—(*Cicadula*)
potoria (Ball)—(*Cicadula*)
***scripta** (DeLong)
slossonae (V. D.)—(*Cicadula*)
variata (Fallén)—(*Cicadula*)

JASSINAE Amyot & Serville
Jassus Fabricius
borealis Spångberg
melanotus Spångberg
olitorius Say
Neocoelidia G. & B.
tumidifrons G. & B.
Paracoelidia Baker
tuberculata Baker, Hocking Co., October 5, 1935, J. S. Caldwell.

BALCLUTHINAE Baker
Balclutha Kirkaldy
abdominalis (V. D.)—(*Eugnathodus*)

impicta (V. D.)
*var. **osborni** V. D.
*var. **maculata** Davidson & DeLong
punctata (Thunberg)
Nesosteles Kirkaldy
***neglecta** (DeLong & Davidson)

CICADELLINAE
Alebra Fieber
albostriella (Fallén)
var. **pallidula** (Walsh)
var. **agresta** McAtee
var. **fulveola** (H.-S.)
*var. **rubrafrons** DeLong, Columbus, July, 1945; Delaware Co., July 8, 1945.
***bicincta** DeLong, Delaware Co., August 9, 1945.
fumida Gillette
Dikraneura Hardy
abnormis (Walsh)
angustata Ball & DeLong
cruentata Gillette
var. **kansiensis** Lawson
maculata Gillette
mali (Prov.)
***mera** McAtee, common on oak in southern and central Ohio.
urbana Ball & DeLong—(*abnormis* var. *urbana*)
Alconeura Ball & DeLong
***macra** Griffith, Hocking Co., April 30
Forcipata DeLong & Caldwell
***loca** DeLong & Caldwell—(*Dikraneura fieberi* (Löw)
***ohioensis** DeLong & Caldwell
Empoasca Walsh
Subgenus **Kybos** Fieber
albolinea Gillette
atrolobes Gillette
aureoviridis (Uhler)
maligna Walsh—(also as *denticula* Gillette)
obtusa Walsh
osborni Hartzell
patula DeLong
pergandei Gillette
smaragdula (Fallén)
trifasciata Gillette
unica Provancher
Subgenus **Hebata** DeLong
alboneura Gillette
Subgenus **Empoasca** Walsh
bicorna DeLong & Caldwell
bifurcata DeLong
birdiae Goding—(*infusca* DeLong)
coccinea Fitch
convergens DeLong & Davidson
***curvatura** Davidson & DeLong
***davidsoni** DeLong—(*mucronata* Davidson & DeLong)
distracta DeLong & Caldwell
ditata DeLong and Caldwell
erigeron DeLong
fabae (Harris)—(also as *flavescens* (Fab.))
hama DeLong & Caldwell
junipera DeLong
lata DeLong & Caldwell
pallida Gillette—(*constricta* DeLong & Davidson)

*perlonga Davidson & DeLong
pyramidata DeLong & Caldwell
radiata Gillette
recta DeLong & Caldwell.
recurvata DeLong
spira DeLong & Caldwell
torqua DeLong & Davidson
venusta DeLong & Davidson
vergens DeLong & Caldwell
Cicadella Dumeril
clavalis (McAtee)—(*Eupteryx*)
flavoscuta (Gillette)—(*Eupteryx*)
***melissae** (Curtis), Put-in-Bay, September 18, 1945, on mint, Mary Auten Trautman, D. J. & J. N. Knull—(*Epteryx*)
nigra (Osborn)—(*Eupteryx*)
Typhlocyba Germar
Ulmi Group
***foliosa** Knull
***piscator** McAtee, Hocking Co., May 25, 1938; Delaware Co., September 9 and 10, 1943; Ashland Co., Mary Auten; Scioto Co., June 9, 1943, June 10, 1944.
***sciotoensis** Knull
***ulmi** Linn., Columbus, at light, summer of 1943. Knulls' residence, one female specimen.
unca McAtee
Rosae Group
***athene** McAtee, Columbus, August, 1944.
aureotecta S. & DeL.
cymba McAtee
duplicata McAtee
froggatti Baker—(*xanthippe* McA.)
gillettei V. D.
var. **apicata** McAtee
var. **casta** McAtee
var. **fitchi** McAtee
var. **russeola** McAtee
*var. **saffrana** McAtee, Delaware Co., May 21, July 2; Fairfield Co., June 16, 1945.
var. **sellata** McAtee
var. **sincera** McAtee
var. **venusta** McAtee
var. **vestita** McAtee
*var. **volans** McAtee, Delaware Co., June 20, 1943.
***hockingensis** Knull
***lancifer** McAtee, Ashland Co., June 26, 1935, Mary Auten; Shawnee Forest, June 9, 1943; Columbus, A.I.U. Tower, June 21, Vergil Argo.
***melite** McAtee
modesta Gibson
phryne McAtee
pomaria McAtee
***putmani** Knull
rosae (L.)
rubriocellata (Malloch)
***shawneeana** Knull
tunicarubra Gillette
Danae Group
antigone McAtee
appendiculata Malloch
berenice McAtee
***eurydice** McAtee, Clifton, June 14, 1938; Franklin Co., July 14, 1942; Monroe Co., July 6, 1943; Hocking Co., July 12, 1943.
***hinei** Knull
nicarete McAtee, common on oak
Hymetta McAtee
anthisma McAtee
balteata Fairbairn
var. **mediana** Fairbairn
distincta Fairbairn
trifasciata (Say)
Erythroneura Fitch
Vulnerata Group
atrata Johnson
***fulmina** McA., Scioto Co., June 17, 1944
nigerrima McAtee
var. **decora** McAtee
nigra (Gillette)
pulchella Rob.
vulnerata Fitch
Obliqua Group
abolla McAtee
aenea Beamer
***alata** Knull
albescens Beamer
alternata Johnson
***amabilis** McAtee, Fairfield Co., June 16, 1945.
autenae Johnson
bicornis Beamer
bitincta McAtee
brundusa Robinson
***caerula** Beamer
caldwelli Johnson
***cauta** Beamer
celebrata Johnson
clavata DeLong
***coarctata** Beamer
complicata Johnson
cornipes Beamer
***cotidiana** Beamer
crataegi Johnson
crevecoeuri (Gillette)
cruciformis Beamer
diffisa Beamer
***divisa** McAtee
dowelli Beamer
electa McAtee
eluta McAtee
fragilis Johnson
fulvocephala Robinson
fumida (Gillette)
funesta Robinson
gleditsia Beamer
hamata Beamer
harpax Beamer
***iconica** McAtee
***idonea** Beamer
inconspicua Johnson
***infinita** Beamer
intricata Johnson
kanza Robinson
latapex Beamer
lawsoniana Baker
magnacalx Beamer
minima Johnson
minuta Johnson
modica Beamer
noeva (Gillette)
nondescripta Johnson
obliqua (Say)
penelutea Beamer

***perita** Beamer
plena Beamer
***praecisa** Knull
repleta Johnson
rubens Beamer
rubrataeniensis Beamer
rubroscuta (Gillette)
rubrotincta Johnson
rufostigmosa Beamer
var. **subnila** Beamer
***sagittata** Beamer
sincera Johnson
sinua Johnson
spatulata Beamer
***spearca** Auten & Johnson, Hocking Co., April 17, 1938, October 17, 1941; Shawnee Forest, June 9, 1943.
stolata McAtee
stylata Johnson
***tenebrosa** Knull
tenuispica Beamer
***torva** Beamer
tridens Beamer
unicuspidis Beamer
volucris Beamer

Maculata Group
abjecta Beamer
accola McAtee
aculeata Beamer
adunca Beamer
aesculi Beamer
affinis Fitch
arta Beamer
certa Beamer
basilaris (Say)
bella McAtee
***bifida** Beamer, Ashland Co., June 16, Mary Auten.
bigemina McAtee
bispinosa Beamer
calamitosa Beamer
campora Robinson
carmini Beamer
certa Robinson
***clara** Beamer, Coal Grove, April 24, 1934, J. S. Caldwell; Lawrence Co., April 29, J. S. Caldwell.
clavipes Beamer
***concisa** Beamer, Hocking Co., July 14, 1934, Mary Auten; Cedar Swamp, September 5, 1941.
confirmata Beamer
***consueta** Beamer, Hocking Co., May 13, 1934, D. M. Johnson; July 14, 1934, Mary Auten.
contracta Beamer
***corylorubra** Knull
crinita Beamer
curta Beamer
***curvata** Beamer, Hocking Co., June 1, 1938.
dira Beamer
dumosa Beamer
***era** McAtee, Pickaway Co., February 20, J. S. Caldwell.
***firma** Beamer, Pickaway Co., February 20, J. S. Caldwell.
***forfex** Beamer, Pickaway Co., March 31, 1934; February 20, and Jackson Co., April 1, J. S. Caldwell.
gemina McAtee
hartii (Gillette)
hymac Robinson
illinoiensis (Gillette)
var. **spectra** McAtee
***impar** Beamer, Port Clinton, May 4, 1934; Pickaway Co., February 20, J. S. Caldwell.
***incondita** Beamer, Hocking Co., April 15, 1934, J. S. C.; May 27, 1934, D. M. Johnson; Pickaway Co., March 31, 1934, February 20, J. S. Caldwell; Hocking Co., May 5.
***inepta** Beamer, Hocking Co., March 27, 1938, Mary Auten.
***ingrata** Beamer, Chesapeake, April 29, 1934, J. S. Caldwell; Pickaway Co, February 20, J. S. Caldwell.
kansana Baker
knighti Beamer
lawsoni Robinson
***lenta** Beamer, Hocking Co., May 5, April 1, 1938, and June 28.
lunata McAtee
maculata (Gillette)
manus Beamer
marra Beamer
minor Beamer
mira Beamer
mirifica Beamer
morgani (DeLong)
***nigriventer** Beamer, Hocking Co., May 8, 1937; Jackson Co., April 1, J. S. Caldwell.
noncuspidis Beamer
osborni (DeLong)
***pallida** Knull & Auten, Hocking Co., March 27, 1938, Mary Auten.
paralleia McAtee
***parva** Beamer, Jackson Co., April 1, 1934, J. S. Caldwell.
***parvipes** Beamer, Pickaway Co., February 20, J. S. Caldwell.
penesica Beamer
propria Beamer
pyra McAtee
***restricta** Beamer, Pickaway Co., March 31, 1934, J. S. Caldwell; Hocking Co., May 5, June 28.
retusa Beamer
rotunda Beamer
***rubranotata** Beamer, Coal Grove, April 24, 1934, J. S. Caldwell.
rubraza Robinson
sancta Beamer
separata Beamer
***spinifera** Beamer, Hocking Co., May 5, June 1, 1938.
tantilla Beamer
torella Robinson
triangulata Beamer
trivittata Robinson
turgida Beamer
***uncinata** Beamer, Hocking Co., June 28.
unica Beamer
usitata Beamer

Tecta Group
ligata McAtee
rosa Robinson

tecta McAtee
Comes Group
aclys McAtee
acuticephala Robinson
amanda McAtee
***aza** Robinson, Cedar Swamp, April 24, 1934, J. S. Caldwell; Delaware Co., August 20, 1943; Hancock Co., August 7, 1939, Mary Auten.
beameri Robinson
***bidens** McAtee, Clifton, June 14, 1938; Hocking Co., June 5 and 19, 1938; Scioto Co., June 10, 1944.
bistrata McAtee
var. **stricta** McAtee—(*vitis* var.)
calycula McAtee—(*tricincta* var.)
cancellata McAtee
comes (Say)
compta McAtee
var. **rufomaculata** McAtee
corni Robinson
cymbium McAtee—(*tricincta* var.)
delicata McAtee—(*lacta* Rob.)
var. **accepta** McAtee—(*scripta* McA.)
diva McAtee—(*tricincta* var.)
elegans McAtee
***festiva** Beamer, Knox Co., September 17, Mary Auten; Richland Co., October 6, Mary Auten; Scioto Co., June 17, 1944.
***fraxa** Robinson, Coal Grove, April 29, 1934, J. S. Caldwell; Scioto Co., June 17, 1944.
infuscata (Gillette)
integra McAtee—(*tricincta* var.)
kanwakae Robinson
***kennedyi** Knull
noncincta Johnson—(*calycula* var.)
nudata McAtee—(*attenuata* Johnson)
omaska Robinson
ontari Robinson
palimpsesta McAtee
pontifex McAtee—(*breakeyi* Johnson)
***prima** Beamer, Hocking Co., August 16, 1945.
prosata Johnson—(*infuscata* var.)
reflecta McA.—(*portea* Rob.)
rubra (Gillette)
rubrella McAtee
tricincta Fitch
vaga Johnson
***vagabunda** Knull
vitifex Fitch
vitis (Harris)
var. **corona** McAtee
ziczac Walsh
var. **walshi** Beamer, Ashland Co., May 8, Mary Auten.

NOTES ON NYMPHS OF THE DRAGONFLY GENUS HELOCORDULIA NEEDHAM

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The genus *Helocordulia* was described by Needham (1901, page 495) to include the species *uhleri* (Selys), recorded from Ontario, Maine, Pennsylvania, and New Jersey, and *selysii* (Hagen) from Georgia and North Carolina. *Helocordulia*, on the basis of adult structure, belongs to Williamson's (1908) Group 1 of the *Cordulinae*. Walker (1925, pages 17–18) subdivides Williamson's main group, affiliating *Helocordulia* with *Tetragoneuria* and *Epicordulia* in Subgroup A, with *Somatochlora*, *Dorocordulia*, and *Cordulia* comprising Subgroup B. There are no several characters that will separate all of the nymphs of the *Cordulinea* from those of the *Libellulinae*, so the genera of the family *Libellulidae* are keyed out together. Within the *Cordulinae*, however, the nymphs may be grouped (as genera) in the following manner:

GROUP 1. (*Helocordulia*, *Tetragoneuria*, *Epicordulia*)—Lateral spines of segment 9 reaching to tip of superior anal appendage or beyond; lateral spines of segment 8 not set at an angle to long axis of abdomen; dorsal hooks well developed, hooked and with a sharp apex; clefts of crenulations on distal margin of lateral lobe shallow or medium in depth, the lobes or teeth about as broad as long, always as broad or broader than depth of adjoining cleft.

GROUP 2. (*Neurocordulia*, *Platycordulia*)—Lateral spines of segment 9 as in Group 1; lateral spines of segment 8 set at an angle to long axis of the abdomen (not so obvious in *N. yamaskanensis* as in *N. obsolata*); dorsal hooks, especially on segments 6 to 9, knob-like with blunt rounded apex; clefts of crenulations on distal margin very deep, the lobes or teeth elongate, dorsal ones twice or more as long as broad.

GROUP 3. (*Somatochlora*, *Dorocordulia*, *Cordulia*)—Lateral spines of segment 9 reaching to or proximal of middle of superior anal appendage (in majority of species hardly reaching to base of appendage); dorsal hooks (with exception of a few species of *Somatochlora*) low rudimentary or altogether absent.

Genus **Helocordulia** Needham

The nymphs of this genus may be separated from all other members of the family *Libellulidae* by the following characters: Clefts of crenulations on distal margin of lateral lobe shallow, one-half or less as deep as lobes or teeth are broad; lobes or teeth about as long as broad, or less.

Large, cultiform dorsal hooks on abdominal segments 7 to 9; a small hook or indistinct mid-dorsal prominence on segment 6; hooks or any indications completely absent from abdominal segments 1 to 5. Lateral spines on segments 8 and 9, those of segment 8 parallel, not at an angle, to long axis of abdomen; those of segment 9 reaching to or slightly beyond tips of superior anal appendage. Superior and lateral anal appendages subequal in length; anal appendages short and stubby, considerably shorter than mid-dorsal length of segments 8 and 9. Distal half of dorsal surface of mentum with no setae (as is characteristic of *Epicordulia*).

KEY TO SPECIES OF HELICORDULIA NYMPHS

Dorsal hook on abdominal segment 6 small, but definitely a spine-like structure with an acute apex (as seen from lateral view); lateral spines of segment 8 subequal to or slightly shorter than those of segment 9 .... Uhleri

Mid-dorsum of segment 6 with a thickened area, a mere suggestion of a tubercle, not spine-like and sharp pointed; lateral spines of segment 8 about one-half those of segment 9, Selysii

Helocordulia uhleri (Selys)

In 1939 the writer recorded *Helocordulia selysii* from Louisiana, based on two male nymphs collected in Bayou Lacombe at the State Fish Hatchery near Mandeville, La., January 9, 1938, and a female nymph from the Tickfaw River at Greensburg, La., January 22, 1938. Although these specimens did not agree in all respects with the description and figures by Kennedy (1924), they were labeled *selysii* because: 1) from known collections *selysii* is a southern and *uhleri* a northern species; 2) the presence of 7 lateral setae stated by Needham (1929) as a distinguishing character (*uhleri* having 6); and 3) the indefinite description of the dorsal hook of segment 6. At a later date, we secured a female nymph from Halls Mill Creek, Mobile County, Alabama, February 12, 1938, and a female nymph from Robinson Creek, Hardin County, Tennessee, June 2, 1945. A study of these specimens and a review of the literature showed that the Alabama and Tennessee specimens as well as those from Louisiana belonged to *uhleri*. This correction should be made to the paper by Wright (1939, page 204). The Tennessee specimen represents the first record of *uhleri*, as well as the genus *Helocordulia*, from that State.

Needham (1901) in his original description of *uhleri* states, "mental setae about 10 or 11, . . . lateral setae seven or six, when seven the basal one smaller than the others . . ." In the Handbook (1929, page 182), Needham gives 6 lateral setae as characteristic of *uhleri* and 7 setae for *selysii*. Kennedy (1924, pages 2 and 3) shows 6 lateral setae and 13 mental setae for *uhleri*. All of our specimens had 7 lateral setae and 12–14 mental setae, composed of 8 or 9 long lateral setae and 4 or 5 short medial setae. Needham (1901) describes the dorsal hook on segment "6 rudimentary, a mere low pointed tubercle." This is a confusing statement as in *uhleri* the dorsal hook of segment 6 is a definite spine-like structure. In our specimens, it is heavily set with denticles so as to somewhat obscure its shape, but viewed laterally it is definitely spine-like, and not a tubercle. Our specimens have the hook of segment 6 one-eighth or somewhat less the size of that of segment 7, and the dorsal hooks of segments 7 to 9 from one-half to as long as the segment bearing them. Lateral spines of segments 8 and 9 subequal, those of segment 9 reaching to or just beyond tips of superior appendage, but not to tips of inferiors. The nymph collected in Hardin County, Tennessee, was examined the same day found and showed the following interesting structural character: Ventral portion of distal margin of segment 9 with a row of large spine-like teeth and a series of very long hairs projecting outward in a fan-like fashion. The hairs are 1.5 to 2 mm. in length and far surpass the tips of the anal appendages. When the nymph was emersed in liquid, this structure was clearly visible. The hairs are easily destroyed after preservation of the nymph, but undoubtedly are typical of the species (and probably genus) as is indicated by remains of portions of the fan-shaped hair tuft in the specimens collected in 1938. In the Tennessee individual, a series of long hairs are present in some areas along the lateral margins of segment 9, but are missing in the greater part. All specimens examined by the writer have spine-like teeth on lateral margins of abdominal segments 2 to 9, increasing in size posteriorly; those on margins of segments 8 and 9 quite large and prominent, being 4 or 5 times the size of those on the proximal segments.

The male appendage, overlying the superior anal appendage, is rectangular in shape, covering about four-fifths of the superior appendage; the distal margin is truncate with rounded lateral angles.

Helocordulia selysii (Hagen)

The nymphal stage of this species has been very adequately described and illustrated by Kennedy (1924). As we have no specimens of *selysii* available for study, the important characters as discussed by Kennedy are given below:

Lateral setae 7; mental setae 13 or 14, composed of 8 very long lateral and 5 or 6 short medial setae. Dorsal hooks of segments 7 to 9 similar to those of *uhleri;* hooks of segment 6 a mere suggestion of a tubercle which was not visible (in exuviae) until the encrusting mud had been scraped away. Lateral spines of segment 8 about one-half the length of those of segment 9; spines of segment 9 more than one-half the length of segment 9, and reaching to tip of superior appendage.

In a letter to the writer dated February 11, 1938, Dr. C. H. Kennedy states, in answer to questions concerning the *Helocordulia selysii* nymph, "I have never felt uncertain of my identifica-

tion of my specimen and nymph taken at Raleigh. This specimen and skin are deposited in the National Museum in Washington so I am not able to study them further. However, before Williamson died he told me he felt very sure that the thing which I called *Helocordulia* was one of the southern species of *Tetragoneuria*. My memory is that he thought it was probably *petechialis*." I have not examined Kennedy's specimens of *selysii*, but, from the characters of the exuviae, it belongs without doubt to the genus *Helocordulia*. Our reasons for this statement are as follows: 1) its close similarity of the nymph of *uhleri*, found in New York by Needham (1901); 2) all of the known nymphs of *Tetragoneuria* and *Epicordulia* have dorsal hooks on segments 2 to 9, the lateral spines of segment 9 are as long or longer than the segment and reach or exceed the tips of the inferior anal appendages; and 3) the separation of the exuviae described by Kennedy from all other genera of *Cordulines* by characters given in the discussion of the generic groups listed in the beginning of this article. It is of interest to note that *Tetragoneuria petechialis* Muttkowski is very close to and often considered a variation of *T. stella* Williamson. The nymph of *petechialis* is unknown, but that of *stella* has been described by supposition and is typical of *Tetragoneuria* in having a complete set of dorsal hooks and long lateral spines on segment 9. There are no other dragonfly nymphs in our faunal area having the combination of characters possessed by *Helocordulia uhleri* and *selysii*.

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A NEW SPECIES OF CYCLOCOELUM (A TREMATODE) FROM THE EASTERN SOLITARY SANDPIPER

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Four specimens of the genus *Cyclocoelum* Brandes were found in the airsac of a solitary sandpiper, *Tringa solitaria solitaria*, by Walter Morrison at Lemont, at the foot of Mt. Nittany, near State College in 1939. They were given to Assistant Professor Merrill Wood, an ornithologist, who presented them to the author for identification and study.

The specimens were in excellent condition for making permanent mounts. They were slightly flattened between microscopic slides, and stained with Delafield's hematoxylin.

At least thirty species of *Cyclocoelum* with well differentiated characters have been described from birds, and are listed in the comparative tables of Bhalerao (1935) and Khan (1935). The species *C. dumetellae* from the catbird (Zeliff, 1943), *C. jaenschi* (Johnson and Simpson, 1940) from the airsac of grebes, in Australia, and *C. turusigi* (Yamaguti, 1939) from *Tringa* may be added. Ten of the species mentioned are from the genus *Tringa*. The specimens from the eastern solitary sandpiper do not check completely enough with those from the several species of *Tringa* nor other species of *Cyclocoelum*. They are herewith described as a new species.

Cyclocoelum nittanyense, n. sp.

Specific diagnosis: Body oblong, anterior third tapering slightly, the posterior fourth rounding slightly, both lateral surfaces with gradual convergence throughout, 10 to 11 mm. in length by 2 to 3 mm. in width; cuticle undulating and rough; oral sucker 0.27 mm. in diameter, subterminal and indistinctly outlined; acetabulum or ventral sucker lacking; pharynx 0.22 mm. in width by 0.24 mm. in length; prepharynx very short; esophagus 0.39 to 0.52 mm. in width by 0.82 mm. in length; intestinal ceca continuous in the posterior end, typical for the genus; excretory bladder between posterior intestinal arc and body wall; testes circular in outline, obliquely located, contiguous, 0.53 mm. to 0.90 mm. in diameter, approximately of equal size; vas deferens not observed; vasa efferentia not observed; cirrus sac terminating slightly behind anterior arc of intestinal bifurcation, 0.63 mm. in length by 0.21 mm. in width at seminal vesicle; seminal vesicle filling about two-thirds of cirrus sac; genital pore at posterior end of pharynx; ovary 0.16 mm. by 0.22 mm. in diameter, toward left lateral surface; seminal receptacle 0.21 mm. in diameter; Mehlis' gland 0.22 mm. in diameter; vitellaria extending from slightly cephalic of cirrus sac to posterior margin of posterior intestinal arc; transverse vitelline ducts, between testes and posterior testis and ovary; ootype and oviduct not observed; Laurer's canal not observed; ova 75 to 90 μ by 105 to 150 μ oval as viewed from above, but flattened and crescentic or pan-shaped from lateral view; receptaculum seminis uterinum present; uterine loops quite chevron-like, uterine wall not distinct in posterior portion.

Host: *Tringa solitaria solitaria.*

Location: Airsac.

Locality: Lemont, Pa.

Type specimen: U. S. N. M. Helm. Coll. No. 36917 paratype also on same slide; two additional specimens in author's collection.

Remarks: The new species from the eastern solitary sandpiper is related to a group proposed by Khan (1935), with the ovary anterior to the testes, and a group in a section of the key made by Harrah (1922) with equal testes, not separated by uterine loops and with loops overlapping the ceca both dorsally and ventrally. Relationships to *C. taxorchis* (Johnson, 1917) of Australia of the first group are not close enough to make comparisons worth while. One of the four specimens has the testes reversed in position.

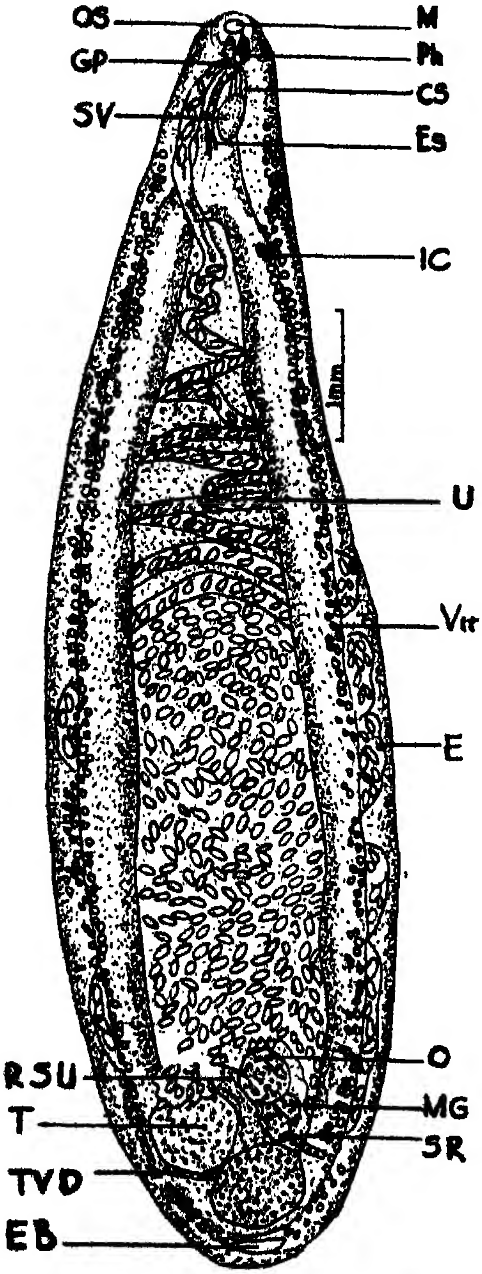

FIG. 1. *Cyclocoelum nittanyense*, n. sp.

Explanation of Figure, ventral view:

CS—cirrus sac
E—egg
EB—excretory bladder
Es—esophagus
GP—genital pore
IC—intestinal cecum
M—mouth
MG—Mehlis' gland
U—uterus
O—ovary
OS—oral sucker
Ph—pharynx
RSU—receptaclum seminis uterinum
SR—seminal receptacle
SV—seminal vesicle
T—testis
TVD—transverse vitelline duct
Vit—vitellaria

C. wilsoni (Harrah, 1922) from *Tringa (Glottis) wilsoni* of N. America and *C. triangularium* (Harrah, 1922) from *Tringa maculata* of N. America both have the testes at the same level rather than obliquely as the species from the eastern solitary sandpiper. The former also has unequal testes, genital pore at the middle of the pharynx, a shorter cirrus sac and less variable size of the eggs. The latter also has more constant size of the eggs and is of smaller size. The following three species have the testes in a position similar to the new species herein described but have the stated, several, major differences and minor differences, as do the previous two species.

Among the variations or differences of *C. halli* (Harrah, 1922), from *Tringa (Totanus) melanoleuca*, are the limitation of the vitellaria laterally to the ceca, size of eggs and location of the ovary toward the right lateral surface. The outstanding variations of *C. tringae* (Brandes, 1892) from *Tringa ocropus*, are the size, shorter cirrus sac, size of the eggs and unequal testes. In *C. brasilianum* (Stossich, 1903), from *Philomachus (Pavocella) pugnax, Tringa (Totanus) flavipes, Totanus melanoleuca*, and *Tringa solitaria* of S. America and in the next species the measurements of the bodies are the closest to this new species. The size of the eggs, shorter cirrus sac and the unequal testes are noticeable variations for this species from the new one. In *C. nebularium* (Khan, 1935) from *Tringa (Glottis) nebularia* from India these same variations occur. From *Tringa erythropus* of Japan, (Yamaguti, 1939) has described *C. turusigi*, which is not closely related. This last species differs from the species herein described by its much greater length, greater dimensions of the organs, location of the testes, and longer ova.

The host of *C. brasilianum* was given as *Scolopax flaviceps* and of *C. tringae* as *Tringa variabilis* by Stossich which names have been subject to rearranging. Khan (1935) lists more hosts for *C. brasilianum* than does its original describer, Stossich (1903). The western solitary sandpiper is now *Tringa solitaria cinnamonea* (Wilson).

According to Joyeux and Baer (1927) *C. triangularum* (Harrah, 1922) and *C. wilsoni* (Harrah, 1922) are synonyms of *C. taxorchis* (Johnson, 1917). Likewise *C. leidyi* (Harrah, 1922) and *C. problematicum* (Stossich, 1902) is a synonym of *C. obscurum* (Leidy, 1887). Also, *C. halli* (Harrah, 1922) is a synonym of *C. brasilianum* (Stossich, 1902). This would obviate comparing the new species with some of the above, assuming that these synonyms are generally acceptable.

Witenberg (1926) described *Cyclocoelum (Corpopyrum) kossacki* from *Evolia (Tringa) alpina* from Russia. This was later placed by Joyeux and Baer (1927) in *Cyclocoelum*. The species herein described differs from this species quite distinctly in size of the organs, especially the testes, and in sizes of the eggs. They are not very different in measurements of bodies. Since the eggs of most worms are quite uniform in shape and constant in size, or range in size; eggs would be expected to be a fairly reliable distinctive characteristic. *Cyclocoelum nittanyense* n. sp. does not match very closely any of the fourteen species listed by Joyeux and Baer (1927) in their table.

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